Vermont Single-Family Existing Homes Overall Report

FINAL

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SUBMITTED TO:
Vermont Public Service Department

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Table of Contents

Figures

Tables

ES Executive Summary

This report summarizes the trends and opportunities for energy efficiency within the existing single-family housing stock in Vermont. It integrates the findings from homeowner telephone surveys conducted in 2015, on-site audits conducted in 2015-2016, and market actor interviews conducted in 2016. The homeowner surveys assessed homeowners' awareness and perception of the energy efficiency of their homes, energy efficiency programs, and emerging technologies. The on-site audits assessed the energy characteristics of homes in order to provide baseline data regarding the existing single-family homes market in Vermont. The market actor interviews assessed the market for emerging technologies, including ductless mini-split heat pumps, heat pump water heaters (HPWH), and home energy management systems (HEMS). The energy efficiency trends and opportunities identified through these research activities are summarized below.

The results presented in this report reflect statewide data encompassing all three Vermont Energy Efficiency Utilities (EEUs), which include Efficiency Vermont, Burlington Electric Department, and Vermont Gas Systems. Because sample sizes were much larger for Efficiency Vermont than for either Burlington Electric Department or Vermont Gas Systems, EEU-specific results often emphasize Efficiency Vermont.[1]

TRENDS

In this section, we summarize the trends in the single-family existing housing stock across the three rounds of baseline studies conducted in 2008, 2011, and 2015-2016.

Awareness of Efficiency Vermont has increased and Energy Efficiency Utility program satisfaction remains high. Ninety-one percent of homeowners were aware of Efficiency Vermont in 2015, up from 85% in 2011 and 59% in 2008. In addition, 84% of homeowners who reported participating in Efficiency Vermont programs were 'satisfied' or 'very satisfied' with their experience, which is similar to previous studies. In 2015, 78% of Burlington Electric Department participants and 86% of Vermont Gas Systems participants reported being satisfied or very satisfied.

Barriers to program participation remain stable. Only 24% of homeowners were aware of the Home Performance with ENERGY STAR Program in 2015, similar to the 27% level from 2011. In addition, lack of awareness was the most common reason given by homeowners for not participating in an Efficiency Vermont, Burlington Electric, or Vermont Gas Systems program. While homeowners are generally concerned about their energy bills, most homeowners believe that their homes are already energy efficient.

[1] Prior reports contain detailed results by energy efficiency utility:
Vermont Single-Family Existing Homes On-site Report. Submitted to Vermont Public Service Department. Submitted by NMR Group, DNV GL, Dorothy Conant, and Energy Futures Group. July 20, 2018.
Survey Analysis of Owners of Existing Homes in Vermont. Submitted to Vermont Public Service Department. Submitted by NMR Group. May 29, 2018.

Certain Vermont home characteristics have consistently improved over time. Characteristics that have shown consistent improvement include flat ceiling insulation (average of R-27 in 2008 to R-30 in 2016), clothes washer efficiency (17% ENERGY STAR® certified in 2008 to 44% in 2016), LEDs (0% of bulbs installed in 2008 to 11% in 2016), programmable thermostats (installed in 24% of homes in 2008 to 39% in 2016), and hot water pipe insulation (installed in 20% of homes in 2008 to 36% in 2016).

Other Vermont home characteristics have exhibited inconsistent improvement. Boiler efficiency improved between 2008 and 2011 (average AFUE of 83 to 86), but then remained stable in 2016. Foundation wall insulation did not change between 2008 and 2011 (average R-11) but increased to R-13 in 2016. Furnace efficiency improved between 2008 and 2011 (average AFUE of 84 to 87), but then declined slightly in 2016 (86 AFUE). Dishwasher efficiency was stable between 2008 and 2011 (16%-18% ENERGY STAR® certified) but improved substantially in 2016 (45% ENERGY STAR® certified).

A few Vermont home characteristics have fluctuated or remained stable. Refrigerator efficiency declined between 2008 and 2011 (23% to 7% ENERGY STAR® certified), then rebounded to 22% in 2016. Duct insulation improved between 2008 and 2011 (installed in 10% to 19% of homes) but declined to 6% in 2016. The average R-value for cathedral ceiling insulation was R-21 in 2008, 2011, and 2016.

Figure 1 illustrates the changes in average R-value, AFUE, percent of measures that are energy efficient, and percent of homes containing efficient measures for many of the characteristics recorded by auditors during the 2008, 2011, and 2016 baseline studies. Energy efficiency improvements are colored dark green, setbacks are colored blue, and characteristics that experienced no change are colored light green.

Figure 1: Changes in Home Efficiency Levels Since 2008

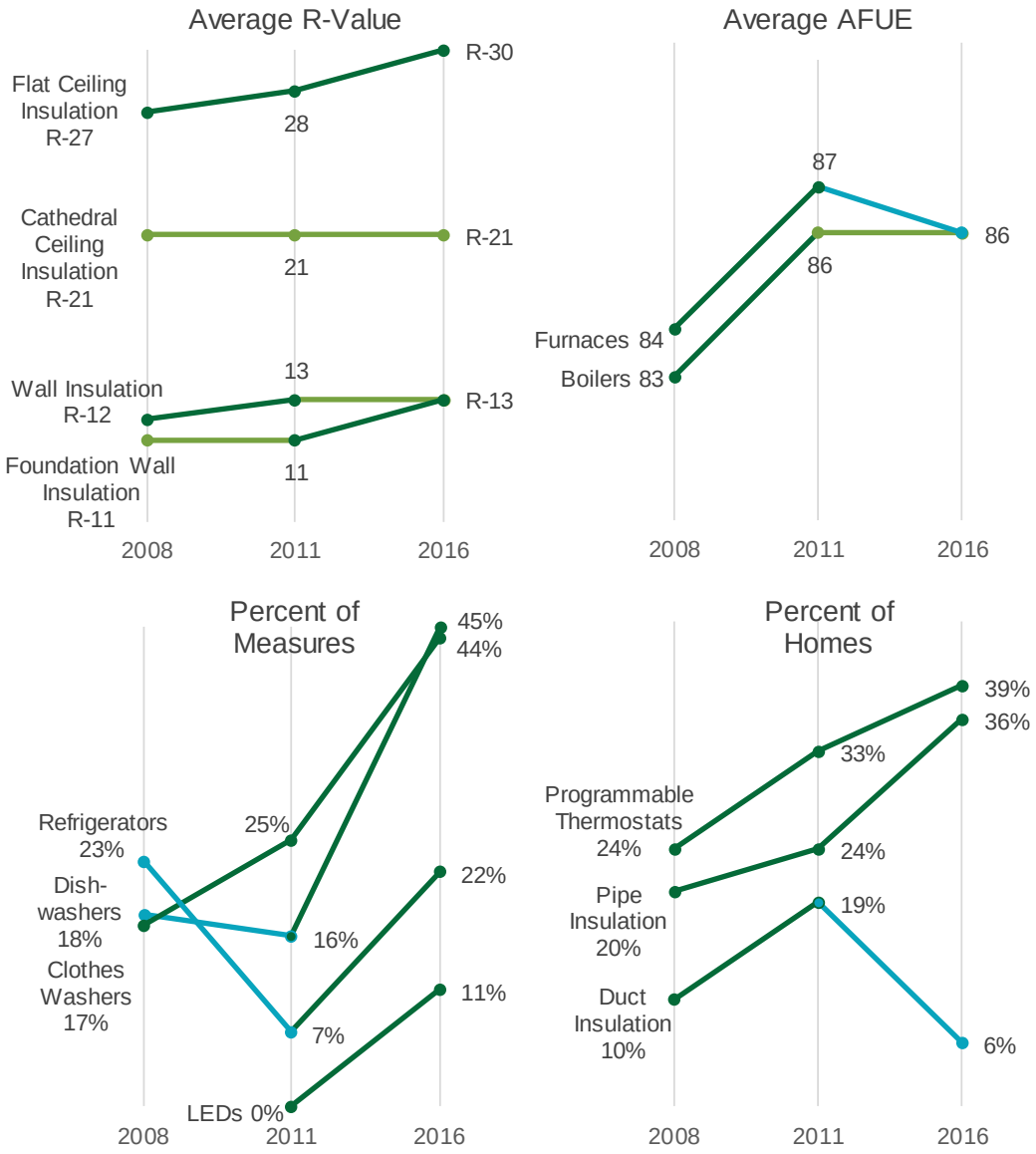
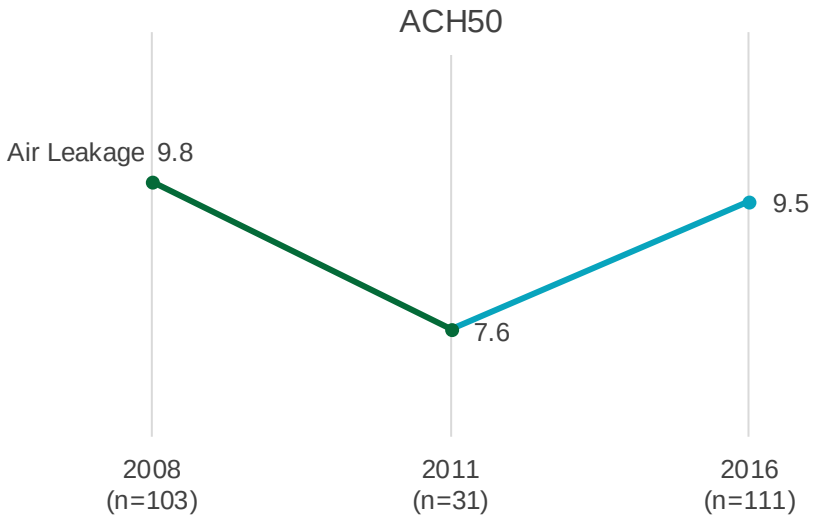


Figure 2 displays the changes in average air leakage over time. Energy efficiency improvements are colored dark green while setbacks are colored blue. Note that far fewer homes (31 homes) received blower door tests in 2011 than in either 2008 or 2016 (100+ homes) so the dip in 2011 may be an artifact of the small sample size. Average air leakage decreased from 9.8 ACH50 in 2008 to 9.5 ACH50 in 2016 – a reduction of only 3%. As a point of comparison, the 9.5 ACH50 value is more than three times the 2015 Vermont

Residential Building Energy Standards (RBES) requirement of 3.0 ACH50 for newly constructed homes.[2]

Figure 2: Change in Air Leakage Since 2008



OPPORTUNITIES

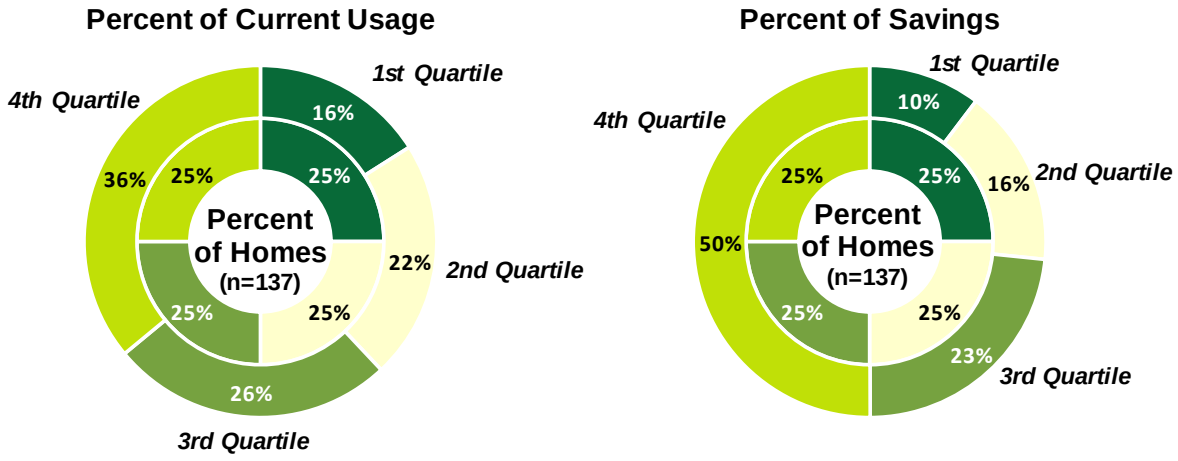
In this section, we summarize the current opportunities in the single-family existing housing stock.

Homeowners who remodel their homes offer an opportunity. Almost one-third (31%) of surveyed homeowners plan to remodel or make significant repairs to their homes in the next year or two, which may offer an opportunity to improve energy efficiency.

[2] 2015 RBES only applies to homes built starting March 1, 2015. The RBES air leakage requirement is presented merely to provide a frame of reference.

Savings opportunities are concentrated with the large energy users. Home Energy Score (HES) models[3] of energy usage found that the 25% of homes with the highest annual energy consumption (the fourth quartile) represent 36% of total energy consumption and 50% of total energy savings opportunities (Figure 3). In contrast, the 25% of homes with the lowest energy usage (the first quartile) reflected only 16% of total consumption and 10% of savings.

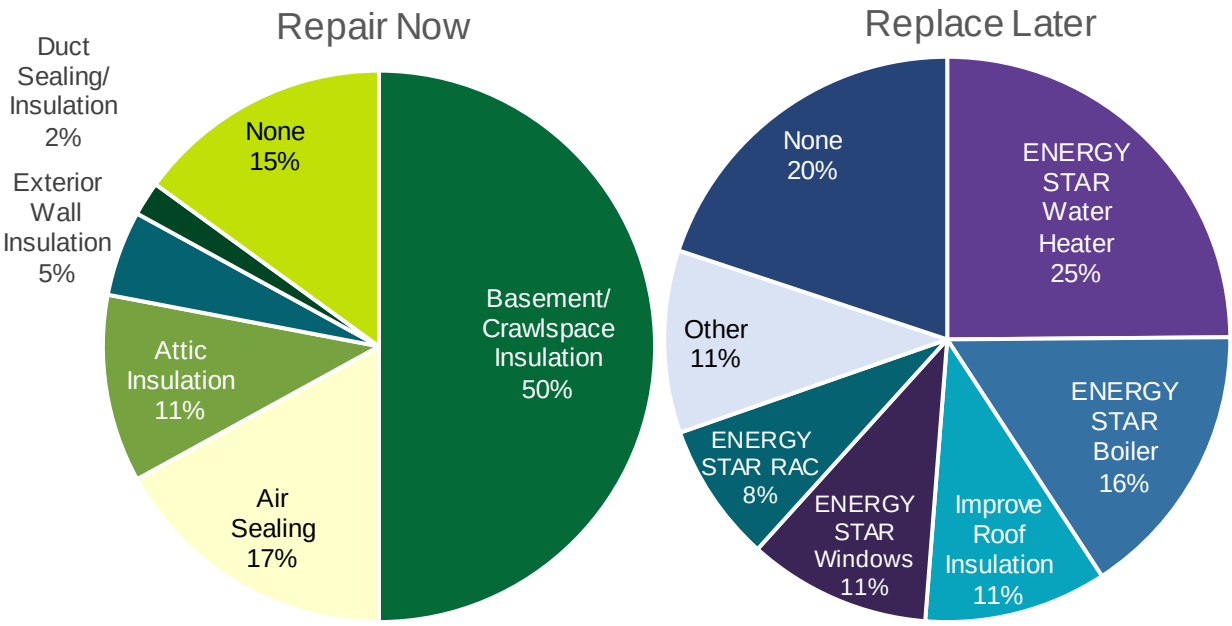
Figure 3: Distribution of Energy Usage and Savings by Quartile



[3] The Home Energy Score is a Department of Energy rating system that models the energy efficiency of homes based on features of the building envelope, glazing, mechanical systems, and home area. The HES tool does not include lighting, appliances, or thermostat set points among its input variables.

Energy modeling identified basement insulation and air sealing as major savings opportunities. The HES tool provides a list of *Repair Now*[4] and *Replace Later*[5] recommendations for each modeled home to improve the home's energy efficiency (Figure 4). Adding basement or crawlspace insulation was the primary *Repair Now* recommendation for 50% of the homes, followed by air sealing (17%) and attic insulation (11%). Installing an ENERGY STAR® water heater was the primary *Replace Later* recommendation for 25% of the homes, followed by installing an ENERGY STAR® boiler (16%), improving roof insulation (11%), and installing ENERGY STAR® windows (11%). Because the HES tool does not consider lighting or appliances, there are no recommendations for these measures.

Figure 4: HES Primary Recommendations

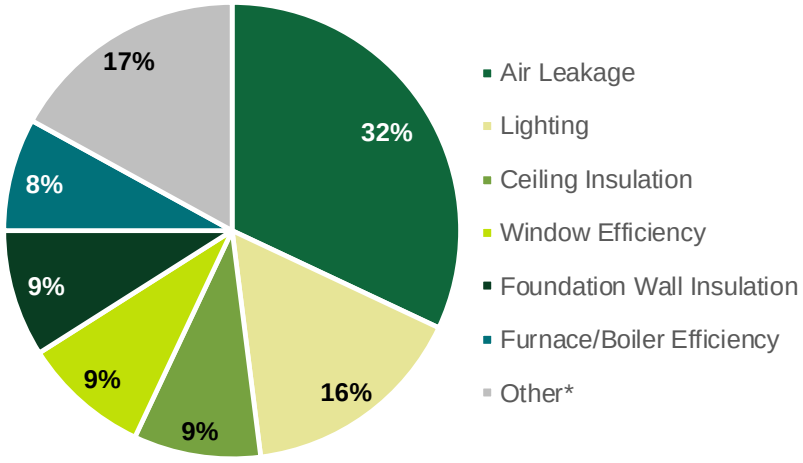


*Includes ENERGY STAR® furnace, heat pump, CAC, and efficient wood stove.

[4] Improvements that "will save you money, conserve energy, and improve your comfort now."
[5] Improvements that "will help you save energy when it's time to replace or upgrade."

Auditors identified air sealing and lighting as major savings opportunities. In addition to the HES modeling recommendations, auditors flagged energy efficiency opportunities during the on-site visits (Figure 5).[6] Nearly one-third (32%) of these energy efficiency opportunities pertain to air leakage, followed by lighting (16%), ceiling insulation (9%), windows (9%), foundation wall insulation (9%), and boiler or furnace efficiency (8%).

Figure 5: Auditor Identified Energy Efficiency Opportunities



*Includes duct insulation/sealing, water heater efficiency, wall, frame floor, door, and knee wall insulation.

[6] Figure 4 includes only the primary (i.e., largest) HES recommendation for each home (excluding lighting and appliances), while Figure 5 includes all auditor-identified recommendations for each home.

Overall, air leakage, lighting, furnaces/boilers, foundation wall insulation, and water heaters appear to be the most promising opportunities. Table 1 summarizes the savings opportunities from the auditor-identified opportunities, the on-site data, and the HES modeling recommendations. The shaded cells reflect those opportunities that were identified via at least two of the three sources.

Table 1: Energy Savings Opportunities and Recommendations

Characteristic	Auditor Identified Opportunities (Percent of Homes)	Savings Opportunities developed from On-site Data	HES Primary Recommendations (Percent of Homes)
Air Leakage	74%	• 30% of homes > 10.0 ACH50	17% Replace Now
Lighting	44%	• 43% saturation of incandescent & halogen bulbs	n/a
Windows	41%	• 5% of window area is single panes without storm windows	11% Replace Later
Furnaces/Boilers	34%	• 23% of homes with furnace/boiler ≥ 20 years old	16% Replace Later
Foundation Wall or Basement Insulation	31%	• 45% of homes with unconditioned basements have uninsulated frame floors and foundation walls	50% Replace Now
Ceiling/Attic Insulation	26%	• 13% of homes ≤ R-19 in flat ceilings • 23% of homes ≤ R-19 in cathedral ceilings	11% Replace Now 11% Replace Later
Water Heaters	16%	• 8% of homes with tankless coil • 25% of homes with electric storage tanks • 34% of storage tanks ≥ 15 years old • 64% of homes with no pipe insulation	25% Replace Later
Duct Sealing/ Insulation	16%	• n/a	2% Replace Now
Wall Insulation	6%	• 3% of homes with no wall insulation	5% Replace Now
Thermostats	4%	• 69% of homes with manual thermostats	n/a
Refrigerators	0%	• 28% of primary refrigerators ≥ 15 years • 46% of secondary refrigerators ≥ 15 years	n/a

Emerging Technologies offer a growing opportunity. Early experiences with emerging technologies suggest that installation and performance issues are relatively uncommon. In addition, customers generally appear to be satisfied with these technologies. Contractor education and training, customer education, and continued financial incentives could accelerate the adoption of these technologies by addressing barriers such as low customer awareness, low contractor confidence and high purchase price.

Table 2 displays homeowner awareness and saturation for heat pumps, HPWHs, HEMs, solar water heaters, and solar PV. Additionally, it summarizes the primary barriers to these technologies and market actors' expectations regarding future sales.

- Customers are more aware of heat pumps and solar water heaters. In contrast, store managers cite low customer awareness as a key barrier to further adoption of HPWHs and HEMs.
- Higher purchase price is a key barrier for HPWHs and solar water heaters as well as solar PV.
- HPWHs require sufficient space, a minimum temperature of 50 degrees, and a drain in order to be installed, which only 30% of visited homes had available.
- Distributors expect heat pumps to continue to dominate sales, and retailers expect supply and demand for HPWHs and HEMs to increase.

Table 2: Emerging Technology Awareness, Saturation, Barriers, and Sales Projections

Emerging Technology	Homeowner Awareness	Percent of Homes with Unit Installed	Barriers	Sales Projections
Heat Pumps	61%	4%	• None Identified	Remain Stable
Heat Pump Water Heaters	37%	1%	• Awareness • Price • Requirements	Increase
Home Energy Management Systems	38%	1%	• Awareness	Increase
Solar Water Heater	69%	4%	• Price • Sunlight	n/a
Photovoltaic Arrays	33%	1%	• Price • Sunlight	n/a

RECOMMENDATIONS

In this section we offer recommendations regarding the savings opportunities that could be targeted by future energy efficiency programs.

Homeowners who plan to remodel their homes. Almost one-third (31%) of survey respondents plan to remodel or make significant repairs to their homes in the next year or

two. These homes may present opportunities for energy improvements, particularly for products that are typically addressed during a remodel, such as lighting, appliances, insulation, and air sealing. Partnering with contractors who specialize in remodeling may offer an avenue to reach these homeowners and leverage their influence on homeowners' decisions.

High energy usage homes. HES modeling indicates that 50% of energy savings opportunities reside in the one-quarter of homes that use the most energy. Therefore, addressing the energy savings opportunities in these high consumption homes offers a clear opportunity to impact overall usage.

Air sealing. Nearly one-third (30%) of homes had ACH50 > 10.0. In addition, auditors identified air leakage as an opportunity in nearly three-quarters (74%) of homes.

Ceiling insulation. Average ceiling insulation R-values have increased minimally since 2008. In addition, auditors identified ceiling insulation as an energy efficiency opportunity in over one-quarter (26%) of on-site homes. Accessible flat ceiling spaces, in particular, present clear opportunities for insulation upgrades combined with air sealing.

Foundation wall insulation. Although the average foundation wall insulation R-value increased slightly since 2008, nearly one-half (45%) of the homes with unconditioned basements lacked both frame floor and foundation wall insulation. Auditors identified foundation wall insulation as an opportunity in nearly one-third (31%) of homes and adding basement/crawlspace insulation was the primary HES *Repair Now* recommendation for one-half of homes. Foundation walls and band joist areas provide a substantial opportunity for insulation and air sealing, depending on the level of finish of the interior.

Furnace and boilers. Twenty-three percent of homes have boilers/furnaces that are over 20 years old and auditors identified furnace/boiler replacements as an opportunity in 34% of homes. Homes with natural gas or propane service and hot water distribution systems offer the opportunity to upgrade to high-efficiency condensing models.

Water heaters. Electric storage tanks are present in 25% of homes while another 8% have tankless coil systems. These homes offer a good opportunity for upgrades to heat pump water heaters assuming they have adequate space and drainage, in particular as the HPWH market evolves.

LEDs. The combined socket saturation of CFLs and LEDs increased from 31% in 2011 to 47% in 2016. However, that leaves 43% of sockets filled with incandescent and halogen bulbs which offers a substantial opportunity to convert additional sockets to LEDs. As long as LEDs remain cost-effective, continuing to incentivize LEDs is appropriate.

Offer contractor education regarding emerging technologies. Distributors report that contractors are most comfortable with technologies they are familiar with and that contractor confidence is critical to a technology's success. In addition, distributors believe that education and training must be provided to contractors in order to enhance their promotion of emerging technologies, such as ductless mini-split heat pumps and heat pump water heaters.

Continue offering financial incentives for emerging technologies. Ductless mini-split heat pumps and solar water heaters were installed in only four percent of homes, while HPWHs, HEMs, and solar PV are installed in only one percent of homes. Interviewees indicated that high purchase prices were a key barrier to the adoption of HPWHs, solar water heaters, and solar PV. In addition, market actors believe that rebates and low interest loans could increase customer uptake of emerging technologies.

Continue exploring savings opportunities in existing homes. Future market assessment studies should continue to identify new opportunities for emerging technologies. In future market assessment studies, consider testing for duct leakage, quantifying the potential opportunities for ductless mini-split and centrally-ducted air source heat pumps, heat pump water heaters, heat pump dryers, drain water heat recovery systems, HEMS, solar photovoltaics, advanced wood heating, electric vehicle charging and the other measures identified in this study and previous studies. This information can be useful in developing programs to address all of these opportunities.

1 Introduction

This report integrates the findings from several research activities undertaken to assess the single-family existing homes market in Vermont. These activities include a homeowner telephone survey, on-site audits, and interviews with market actors such as contractors, retailers, and distributors. Table 3 summarizes the research methods, targeted populations, data collection time periods, and sample sizes.

Table 3: Vermont Single-Family Existing Homes Research Activities

Research Activity	Population	Data Collection Time Period	Sample Size
Telephone survey	Single-family Homeowners	Oct 2015	508
On-site visits	Single-family Homes	Nov 2015 – July 2016	140
Interviews	HVAC Contractors	July – Aug 2016	10
Interviews	Retailers	Nov – Dec 2016	5
Interviews	HVAC Distributors	Nov 2016 – Jan 2017	4

The objectives of the existing homeowner survey included assessing homeowners' perception of the energy efficiency of their homes, awareness and participation in energy efficiency programs, and awareness and penetration of emerging technologies. In addition, the phone survey served as a vehicle to recruit volunteers for subsequent on-site visits. Similar homeowner surveys were completed in 2008 and 2011.

The primary objective of the on-site inspections was to assess the energy characteristics of existing single-family homes in order to provide baseline data regarding the existing single-family homes market in Vermont. Auditors collected data on insulation, air leakage, HVAC equipment, water heating equipment, ducts, appliances, and light bulbs. They also gathered data on emerging technologies including home energy management (HEM) systems, solar net metering, ductless mini-split heat pumps, and HPWHs. Auditors identified potential opportunities for energy efficiency improvements in each home. In addition, the NMR team entered the on-site data into the U.S. DOE Home Energy Score (HES)[7] tool, which rates homes by their energy efficiency and provides specific recommendations to improve the efficiency of the homes. Similar on-site visits were completed in 2008 and 2011.

The market actor interviews assessed the market for emerging technologies, including customer demand and barriers to adoption. Table 3 displays the technologies discussed during the interviews by market actor type.

[7] The Home Energy Score (HES) is a U.S. DOE energy efficiency rating system that models the efficiency of homes based on features of the building envelope, glazing, mechanical systems, and home area. https://betterbuildingssolutioncenter.energy.gov/home-energy-score

Table 4: Technologies Included in Market Actor Interviews

Technology	HVAC Contractors	HVAC Distributors	Retailers
Central wood pellet furnaces and boilers	✓	✓	
Ducted air source heat pumps	✓	✓	
Ductless heat pumps	✓	✓	
Furnaces with an ECM fan	✓	✓	
Ground source heat pumps	✓	✓	
Heat pump water heaters	✓	✓	✓
High performance circulator pumps	✓	✓	
Home energy management systems			✓
Solar hot water systems	✓	✓	

EXISTING HOMES MARKET IN VERMONT

Table 5 summarizes the housing characteristic data for single-family, owner-occupied Vermont homes built before 2005 from the 2009-2013 American Community Survey (ACS). About one-quarter (26%) of the buildings were constructed before 1939, and over one-half (57%) were constructed between 1960 and 1999. About one-half (51%) are heated with oil, one-fifth (22%) are heated with wood, 14% are heated with bottled gas, and 11% are heated with natural gas. On average, 2.4 people reside in these homes.

Table 5: Summary of ACS data and On-site data for Vermont Single-Family Owner-Occupied Homes

Characteristic	Vermont ACS 2009-2013[a]	On-site Sample
Number of Housing Units	*164,600*	*140*
When Structure Built		
Before 1939	26%	23%
1940 to 1959	11%	13%
1960 to 1979	27%	31%
1980 to 1999	30%	26%
2000 or later	6%	8%
Primary Heating Fuel		
Fuel oil	51%	32%
Wood	22%	24%
Bottled gas	14%	23%
Natural gas from underground pipes	11%	12%
Electricity	1%	3%
Other	2%	5%
Average Household Size	2.4	2.1

[a] ACS base = owner-occupied, single-family units built before 2005.

Potential bias is a concern in any sample based on voluntary participation. Compared to the 2009-2013 American Community Survey for Vermont, the on-site homes are similar in

terms of decade of construction and average number of occupants. The on-site homes are also generally similar to the ACS in terms of primary heating fuel, although there are fewer homes heated with oil (32% compared to 51%), and more homes heated with bottled gas (23% compared to 14%). Overall, this comparison suggests that the sample of on-site homes is generally consistent with ACS data on the existing housing stock in Vermont.

SAMPLE PLAN

A dual frame sample, including both random digit dial (RDD) landlines and cell phones was used to reach eligible telephone survey respondents. The phone survey was used as a vehicle to recruit volunteers for subsequent on-site visits. Respondents were screened to ensure that their homes met the following definition of single-family homes from the *Final Definitions for 2011 Residential Market Characterization Study*[8] memo:

- Detached single-family home
    - Constructed on site using a foundation; usually built with wood framing, but also could be built from brick, metal, or another material
    - Modular home that is built at a factory in separate units then assembled and set onto a foundation
- Two-family home or duplex

This definition of single-family homes excludes the following types of homes:

- Part of a building with three or more units (including attached homes)
- Manufactured home that was built at a factory and delivered as a single unit, often known as a mobile home, or single or double-wide trailer

The definition of existing homes includes only those homes built prior to 2005, according to the homeowner. Because owner occupants are the primary decision-makers for their homes (rather than landlords, who are the primary decision-makers for rental homes), the sample was restricted to owner-occupied homes.

The interview samples for the contractor, distributor, and retailer interviews were generated from lists supplied by Efficiency Vermont as well as internet searches. Contractors were screened to include only those who had installed HVAC systems in at least 10 homes over the past few years. Due to a poor response from non-participants, nine of the ten contractor interviews were completed with participants in Vermont energy efficiency programs. The four HVAC equipment distributors interviewed are estimated to supply approximately 80% of the Vermont market.[9] Of the five retailer interviews completed, three were regarding HPWHs and two were regarding HEMS.

The remainder of this report is organized as follows: first, we present trends in homeowner perceptions and observed efficiency levels to illustrate how the market has changed over

[8] *Final Definitions for 2011 Residential Market Characterization Study.* April 14, 2011
[9] Email correspondence with Efficiency Vermont HVAC Program Manager, 10/26/2017.

time. These trends are based on comparisons across the three rounds of homeowner surveys and on-site visits. Next, we identify possible sources of energy savings in existing homes. Sources of energy savings are derived from auditor observations in addition to HES models developed from the on-site data. In addition, we examine potential energy savings from emerging technologies based on findings from the homeowner survey, on-sites, and market actor interviews.

2 Trends

The objective of this section is to illustrate how the single-family existing homes market has changed over time. It includes the following topics:

- Homeowner perceptions
- Observed home efficiency levels

Trends in homeowner perceptions are based on three rounds of homeowner telephone surveys, while trends in observed efficiency levels are based on three rounds of on-site studies.

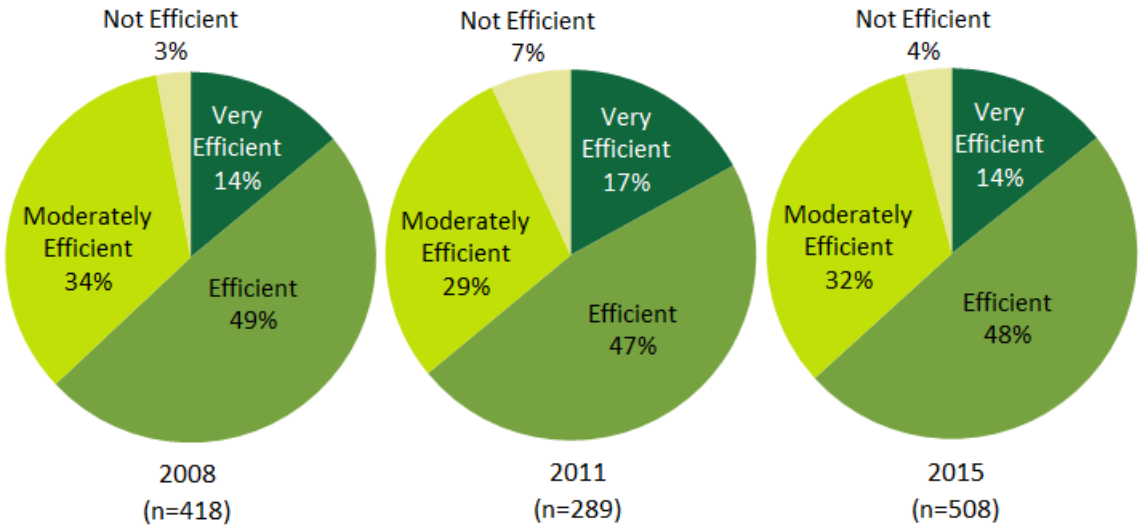
HOMEOWNER PERCEPTIONS

In this section, we summarize the comparison of key questions that were asked in the 2008, 2011, and 2015 telephone surveys with owners of single-family existing homes.

Respondents' perception of the energy efficiency of their home has remained relatively constant, with almost one-half of respondents rating their home as "efficient", one-third rating it "moderately efficient", and about 15% rating it "very efficient".

Figure 6: Respondent Home Energy Efficiency Perceptions (2008, 2011, and 2015)

(Base: All respondents*)



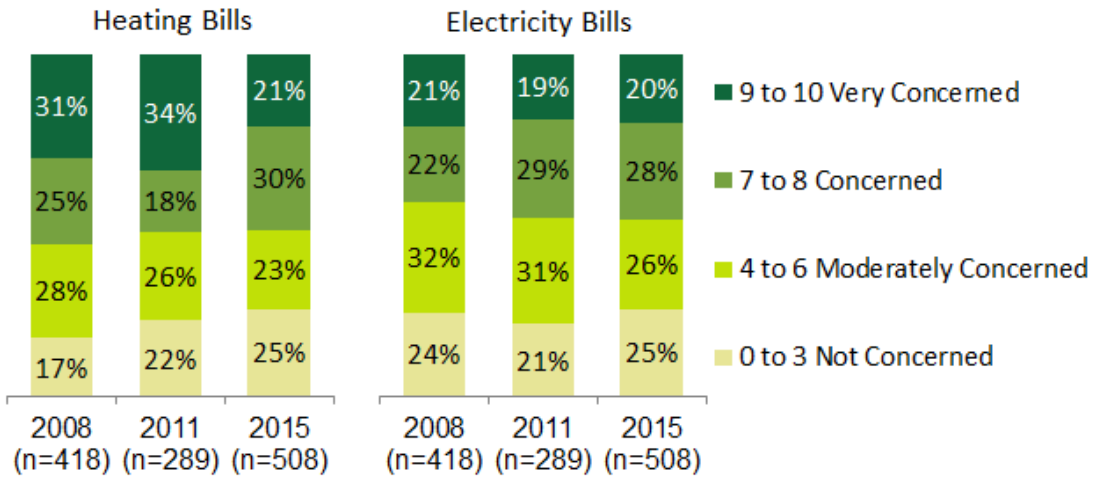
*Results from each survey were weighted by their own weighting scheme.

Even though homeowners believe their homes are energy efficient, they recognize that there are opportunities to improve the energy efficiency of their homes. Nearly three-quarters of respondents (72% in 2011 and 74% in 2015)[10] said that there were ways in which the energy efficiency of their home could be improved.

Respondent concern over heating bills has declined slightly over time, while concern over electricity bills has increased slightly. Figure 7 displays homeowners' ratings of their level of concern over heating and electricity bills on a zero to ten scale. In 2008, 56% of respondents were "concerned" (7 to 8) or "very concerned" (9 to 10) over their heating bills, compared to 52% in 2011 and 51% in 2015. Meanwhile, the percentage of respondents "concerned" (7 to 8) or "very concerned" (9 to 10) over their electricity bills increased from 43% in 2008 to 48% in 2011 and 2015.

Figure 7: Concern with Heating Bills and Electricity Bills (2008, 2011, and 2015)

(Base: All respondents*)



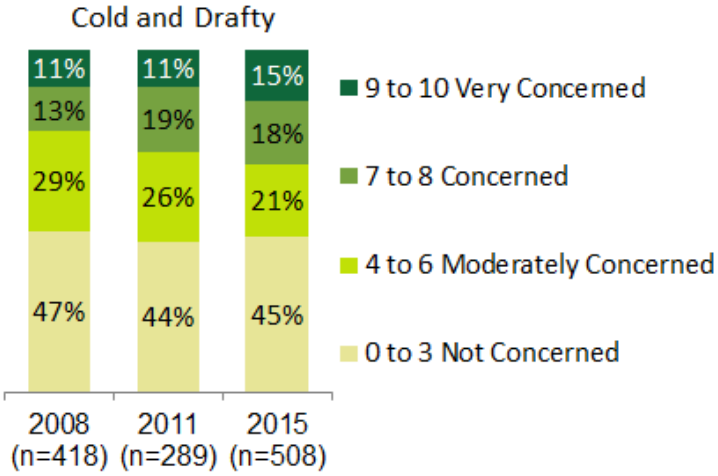
*Results from each survey were weighted by their own weighting scheme.

[10] Homeowners were not asked about opportunities to improve the energy efficiency of their homes in 2008.

Respondents appear to be increasingly concerned about their homes feeling cold and drafty in the winter. The proportion of respondents who were “concerned” or “very concerned” increased from 24% in 2008 to 30% in 2011 then to 33% in 2015.

Figure 8: Concern about Home Feeling Cold and Drafty in Winter (2008, 2011, and 2015)

(Base: All respondents*)



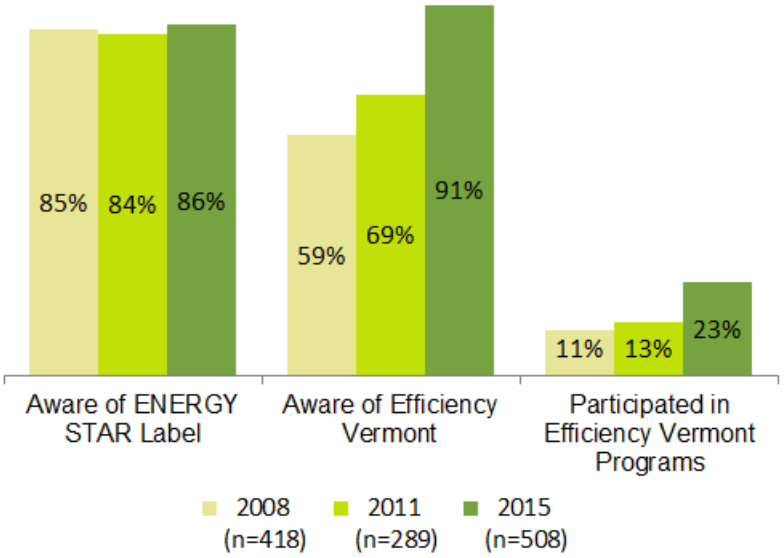
*Results from each survey were weighted by their own weighting scheme.

Awareness of the ENERGY STAR® label in Vermont has remained stable at about 85% since 2008 (Figure 9). However, awareness of Efficiency Vermont and self-reported program participation have steadily increased over the years. Efficiency Vermont recognition increased from 59% in 2008 to 91% in 2015. Meanwhile, self-reported participation in Efficiency Vermont programs doubled from 11% in 2008 to 23% in 2015. Twenty-five percent of Burlington Electric Department respondents and 19% of Vermont Gas Systems respondents reported participating in their programs in 2015.

Fifty-seven percent of the respondents who reported participating in Efficiency Vermont programs in 2015 mentioned the energy audit program, comprehensive energy improvements, and/or Home Performance with ENERGY STAR®, which are likely the same program.

Awareness of the Home Performance with ENERGY STAR program remained stable at 27% in 2011 and 24% in 2015.

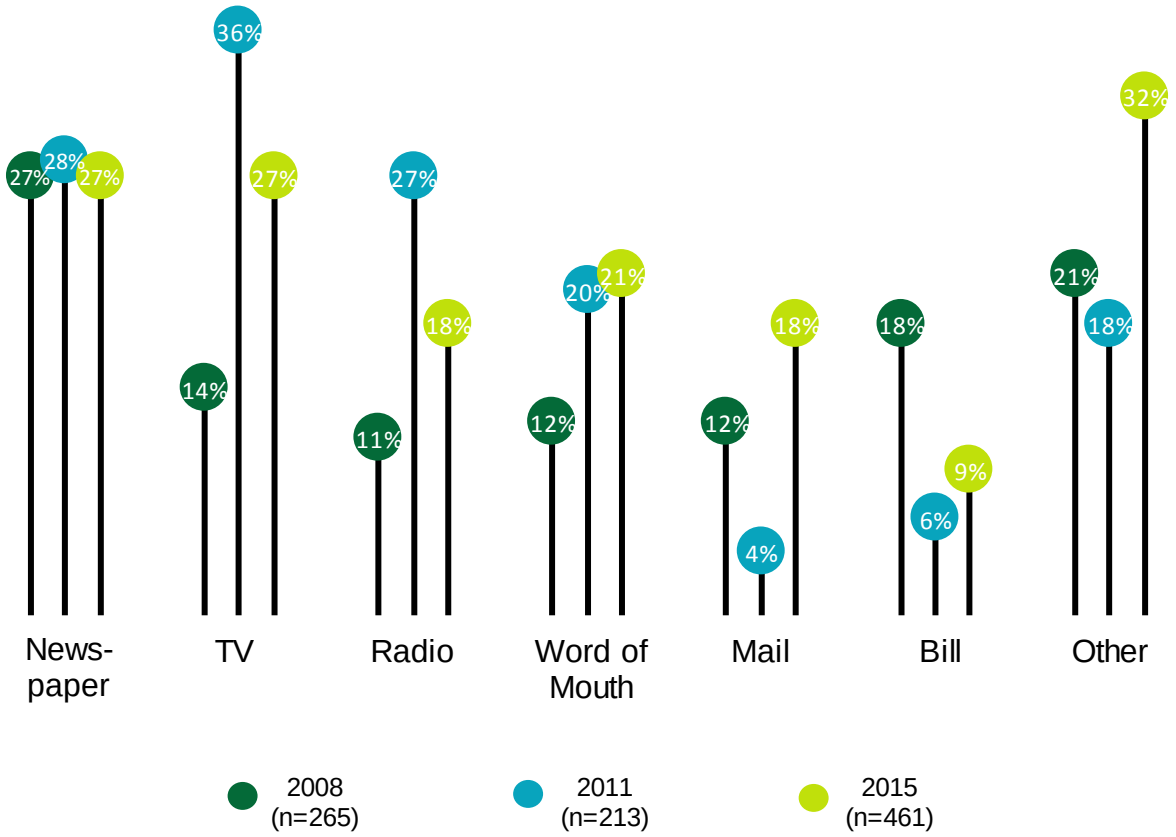
Figure 9: ENERGY STAR® Label Awareness and Efficiency Vermont Awareness and Program Participation (2008, 2011, and 2015)
(Base: All respondents*)



*Results from each survey were weighted by their own weighting scheme.

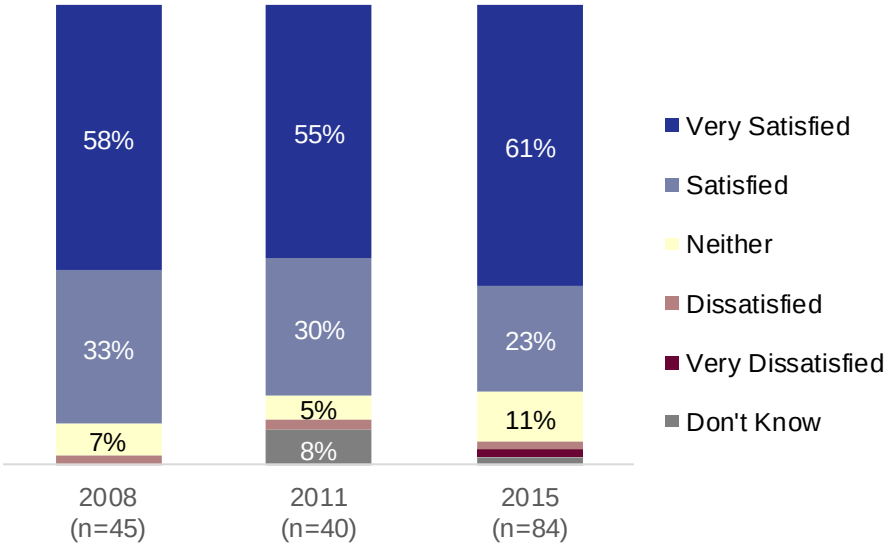
Homeowners heard about Efficiency Vermont in numerous ways. The percentage of survey respondents that heard about Efficiency Vermont in the newspaper has changed very little over time, whereas the percentage of respondents that heard about Efficiency Vermont through TV, radio, word of mouth, and mail has increased. Meanwhile, the percentage of respondents that heard about Efficiency Vermont through their bills has declined.

Figure 10: How Homeowners Heard of Efficiency Vermont



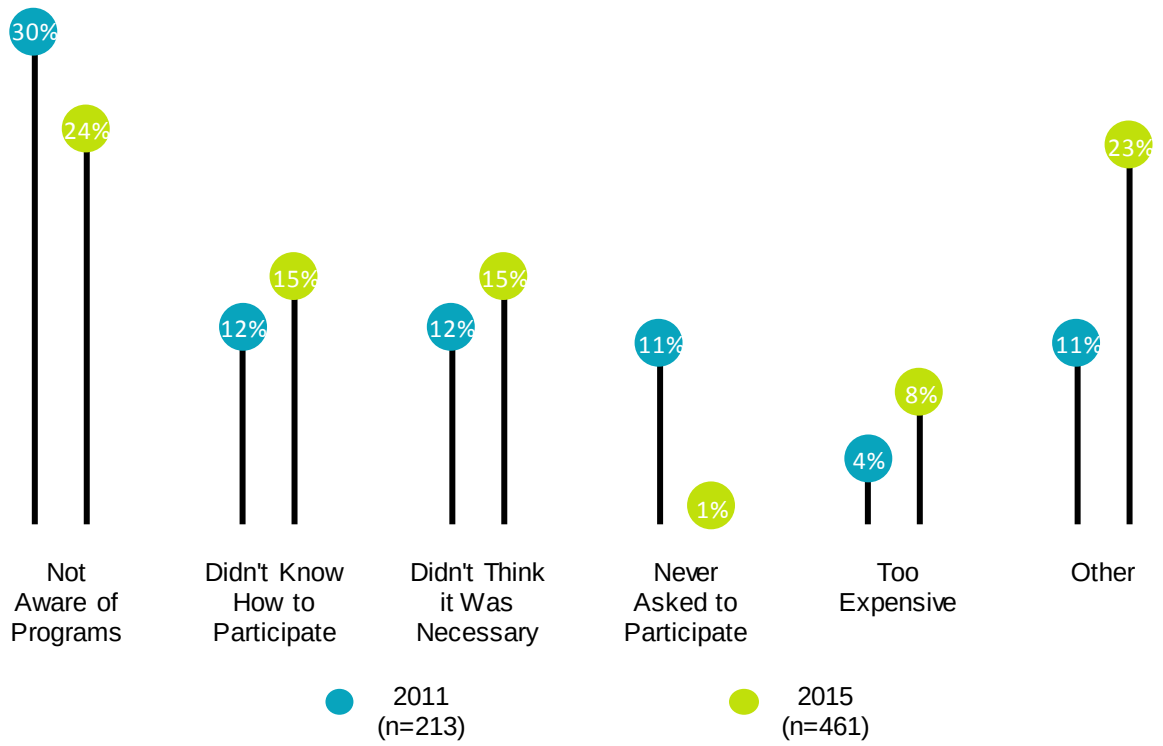
Satisfaction among Efficiency Vermont program participants has historically been high, with more than 80% of participants reporting being satisfied or very satisfied since 2008. In 2015, 78% of Burlington Electric Department participants and 86% of Vermont Gas Systems participants reported being satisfied or very satisfied.

Figure 11: Satisfaction with Efficiency Vermont Programs



Since awareness in Efficiency Vermont programs has increased, homeowners' reasons for not participating in an Efficiency Vermont program have shifted away from lack of awareness towards other reasons, such as not knowing how to participate, not believing it is necessary to participate, and believing that participating would be too expensive.[11] Nevertheless, lack of awareness was the most common reason given by homeowners for not participating in an Efficiency Vermont program in both 2011 and 2015. Reasons for not participating in Burlington Electric Department and Vermont Gas Systems programs were similar to those given for Efficiency Vermont programs.

Figure 12: Reasons for Not Participating in an Efficiency Vermont Program

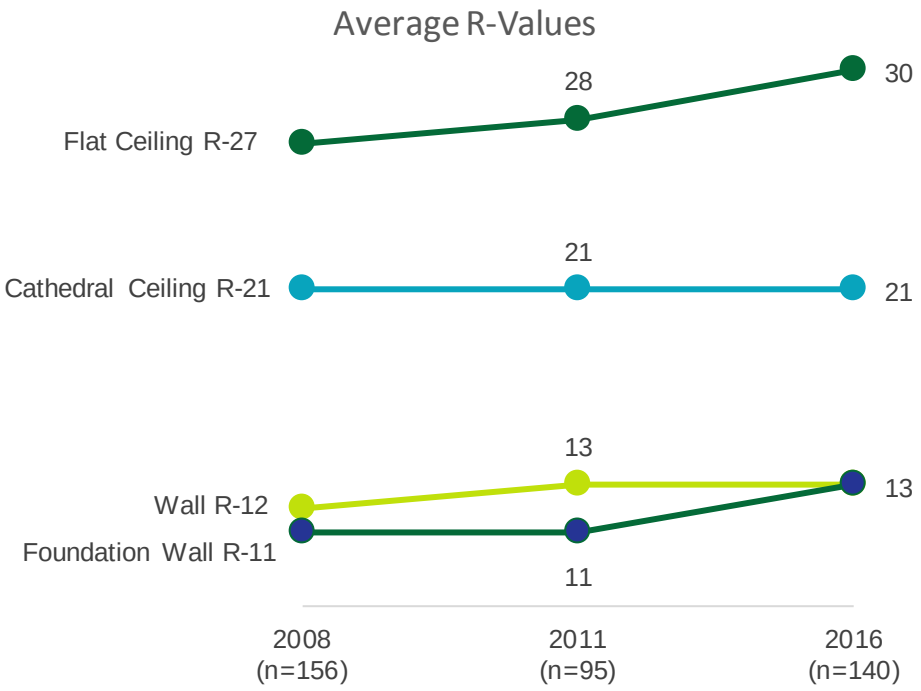


[11] Homeowners were not asked why they did not participate in Efficiency Vermont programs in 2008.

OBSERVED HOME EFFICIENCY LEVELS

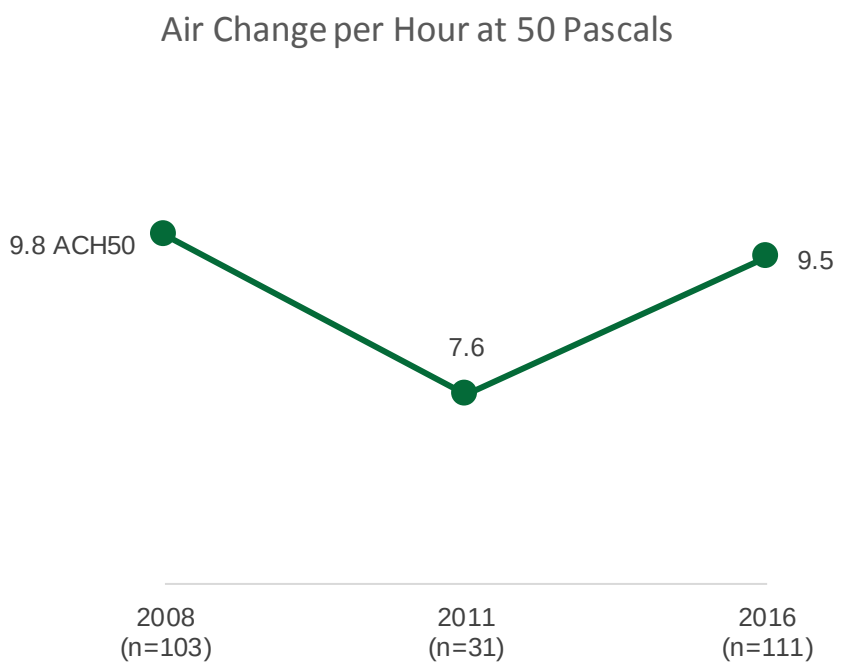
Average cathedral ceiling and wall insulation R-values for Vermont single-family homes have remained relatively consistent since the 2008 baseline study. However, average flat ceiling and foundation wall insulation R-values have increased slightly since 2008 (Figure 13).

Figure 13: Average Wall and Ceiling Insulation R-values Over Time



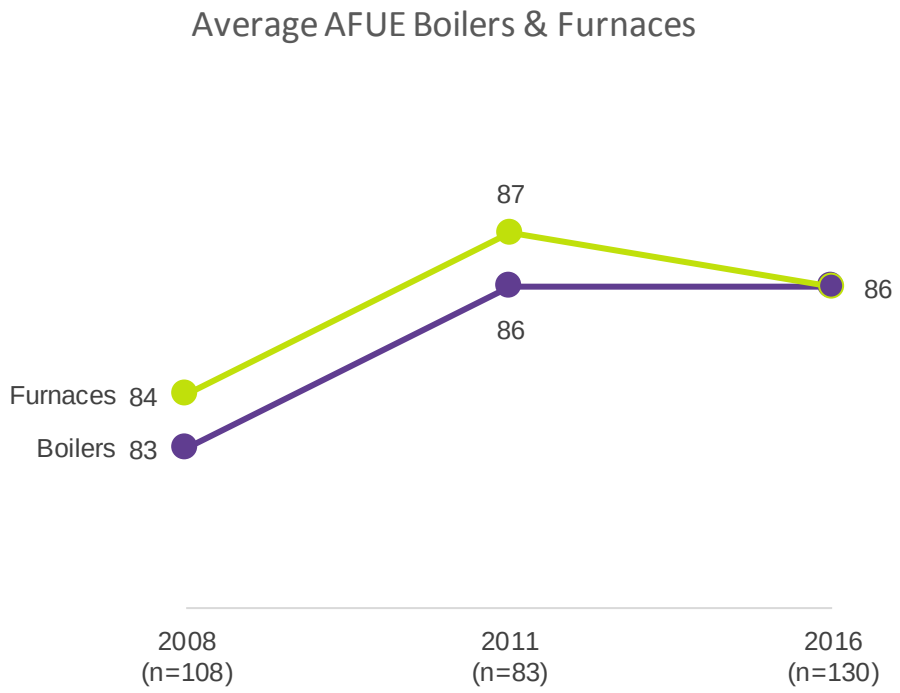
Air leakage, measured in air changes per hour at 50 pascals (ACH50), decreased between 2008 and 2011 but then increased in 2016 (Figure 14). Note, however, that far fewer homes (31 homes) received blower door tests in 2011 than in 2008 or 2016 (100+ homes) so this dip may be an artifact of the small sample size in 2011.

Figure 14: Air Leakage Over Time



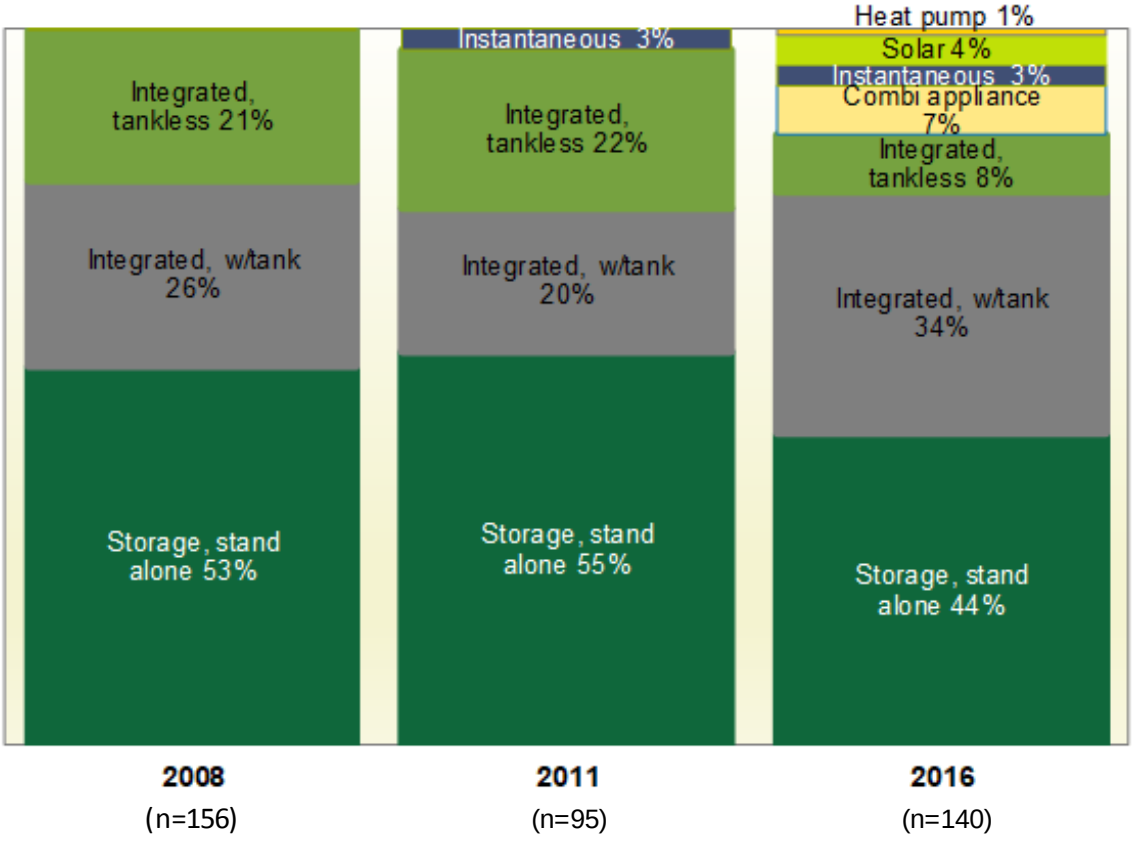
Both boiler and furnace efficiencies increased between 2008 and 2011. However, since 2011, boiler efficiencies increased by less than one percentage point, while furnace efficiencies decreased by one percentage point (Figure 15).

Figure 15: Boiler and Furnace Efficiencies Over Time



For the first time, some inspected homes have water heaters that are solar assisted (4%), heat pump (1%)[12], or a combination appliance[13] (7%) (Figure 16). Compared to the previous studies, more homes have integrated tank water heaters (34%), while fewer homes have integrated tankless (8%) or standalone storage (44%) water heaters.

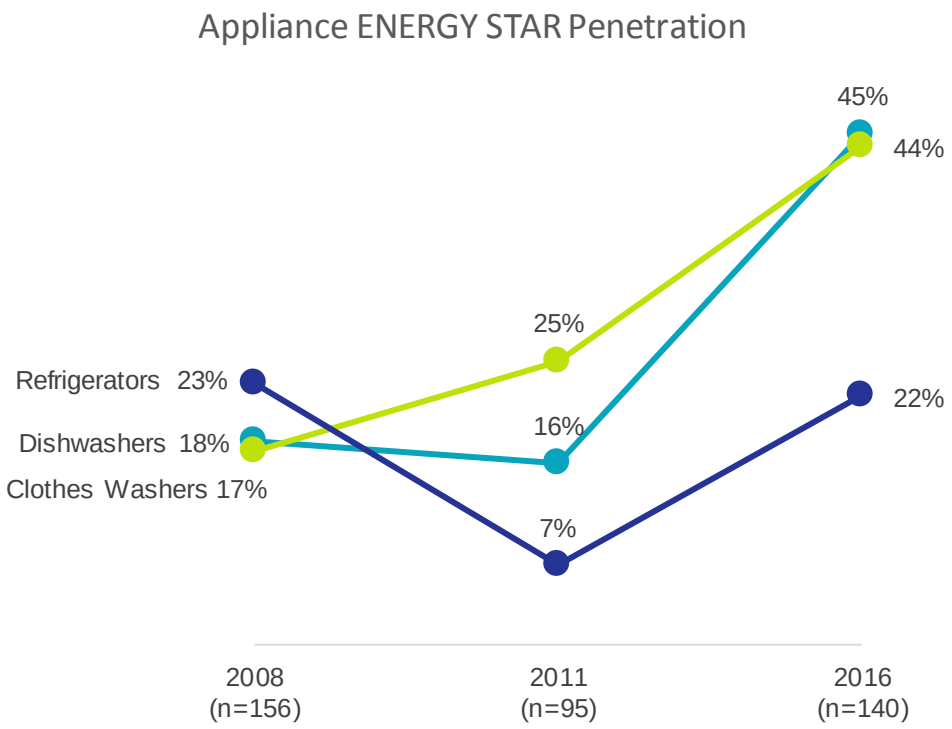
Figure 16: Water Heater Types Over Time



[12] The on-site visits occurred between November 2015 and July 2016, before the rapid growth of the heat pump water heater market.
[13] A combination appliance is both a high efficiency boiler and high efficiency water heater combined in the same unit.

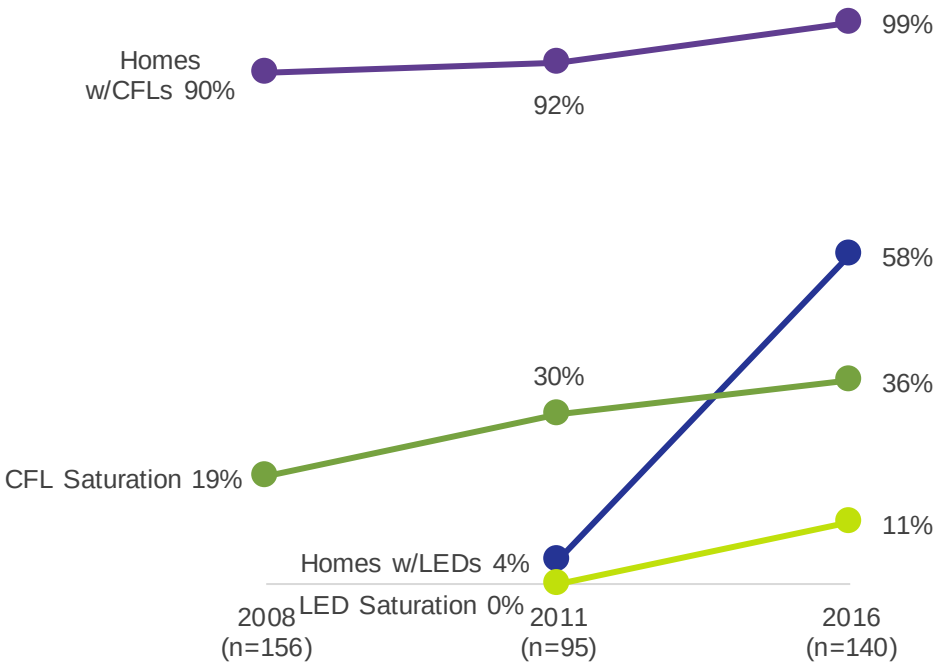
The proportions of dishwashers and clothes washers that are ENERGY STAR® certified have increased since 2008, to 45% and 44%, respectively. However, the proportion of primary refrigerators that are ENERGY STAR® certified has fluctuated and remained below 25% since 2008 (Figure 17).

Figure 17: ENERGY STAR® Clothes Washers, Dishwashers and Primary Refrigerators Over Time



The percentage of homes with at least one LED rose to 58% in 2016, when 11% of sockets contained an LED. CFL penetration[14] and saturation[15] also increased in 2016, to 99% and 36%, respectively (Figure 18). Combined, LEDs and CFLs filled 47% of all sockets in 2016, after filling 30% of all sockets in 2011.

Figure 18: CFL and LED Lighting Over Time



[14] Penetration equals the percent of homes with at least one of a given bulb type installed.
[15] Saturation equals the percent of sockets that contain a given bulb type.

3 Opportunities

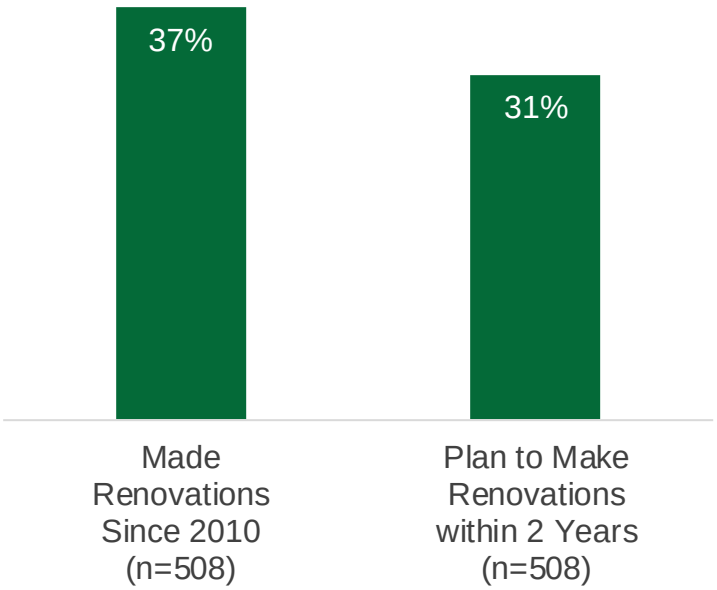
This section presents energy savings opportunities from the homeowner survey, on-site audits, and market actor interviews. It includes the following topics:

- Homeowner decision making
- Observed energy savings opportunities
- Emerging technologies

HOMEOWNER DECISION MAKING

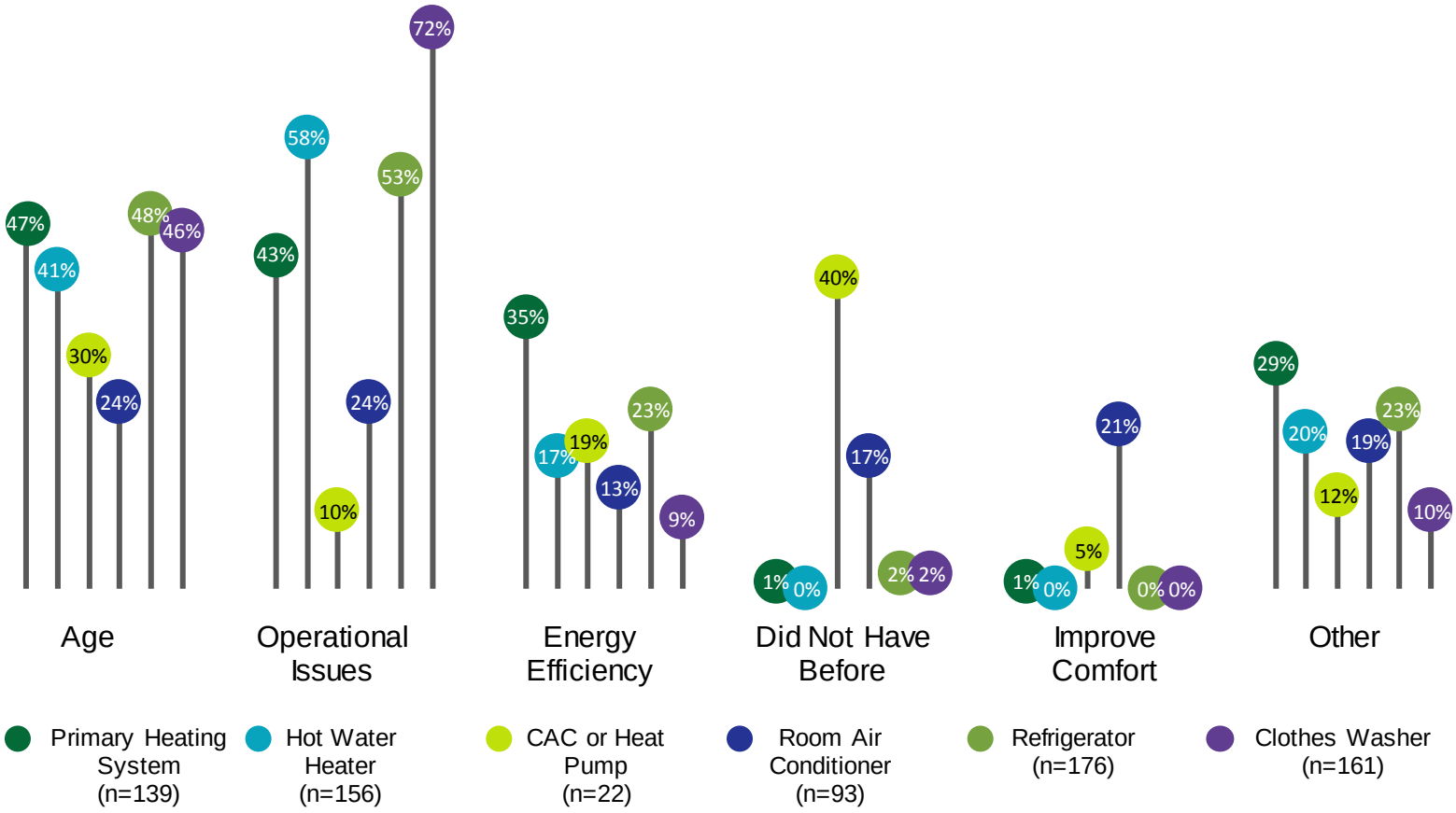
Thirty-seven percent of surveyed homeowners have made renovations, alterations, additions or repairs that impacted the energy usage of their home since 2010 (Figure 19). The most common types of alterations or repairs made by respondents include adding insulation (37%), installing new windows (31%), replacing the roof (15%), and replacing the primary heating system (15%). In addition, 31% of homeowners plan to remodel or make significant repairs to their homes in the next year or two. Respondents who have moved into their homes within the past five years are most likely to have plans to remodel in the near future.

Figure 19: Homeowner Renovations Impacting Energy Usage



Respondents most often purchased products for their home because they thought their existing unit was at the end of its useful life. The most common reason for replacing primary heating systems and water heaters are due to age (47% and 41%, respectively) and operational issues (43% and 58%, respectively) although energy efficiency was also mentioned (35% and 17%, respectively). Similarly, respondents were most likely to replace refrigerators and clothes washers because of age (48% and 46%, respectively) and operational issues (53% and 72%, respectively) although energy efficiency was also mentioned (23% and 9%, respectively). In addition, 40% of the 22 respondents that installed central air conditioning or heat pumps did not have them before. Respondents were most likely to replace room air conditioners because of operational issues (24%) or age (24%).

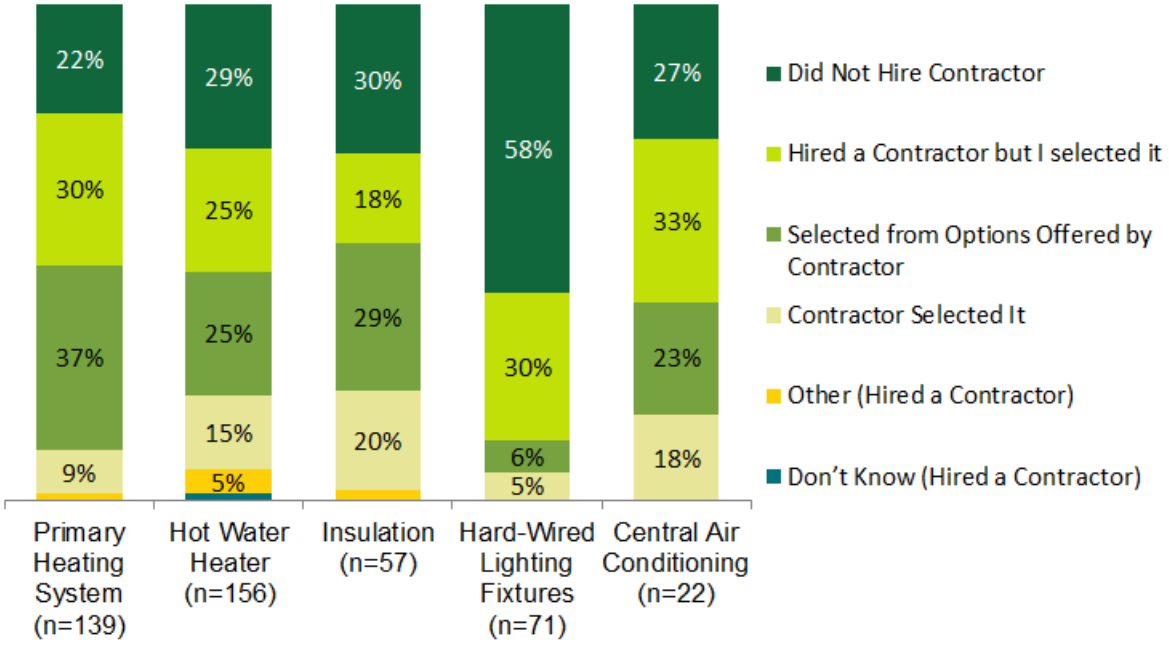
Figure 20: Reasons for Replacing Products (multiple responses)



The majority of respondents who replaced or installed a primary heating system, hot water heater, insulation, or central air conditioning/heat pump hired a contractor (Figure 21). In contrast, less than one-half (42%) of respondents who installed hard-wired lighting fixtures hired a contractor. Contractors had the largest influence on the selection of insulation: nearly one-half of respondents who installed or replaced insulation said they selected it from among options offered by their contractor (29%) or their contractor selected it (20%). In addition, 46% of respondents who installed a primary heating system and 40% each of respondents who installed a hot water heater or central air conditioning/heat pump said they selected the model from among the options offered by their contractor or the contractor selected it.

Figure 21: Role of Contractor

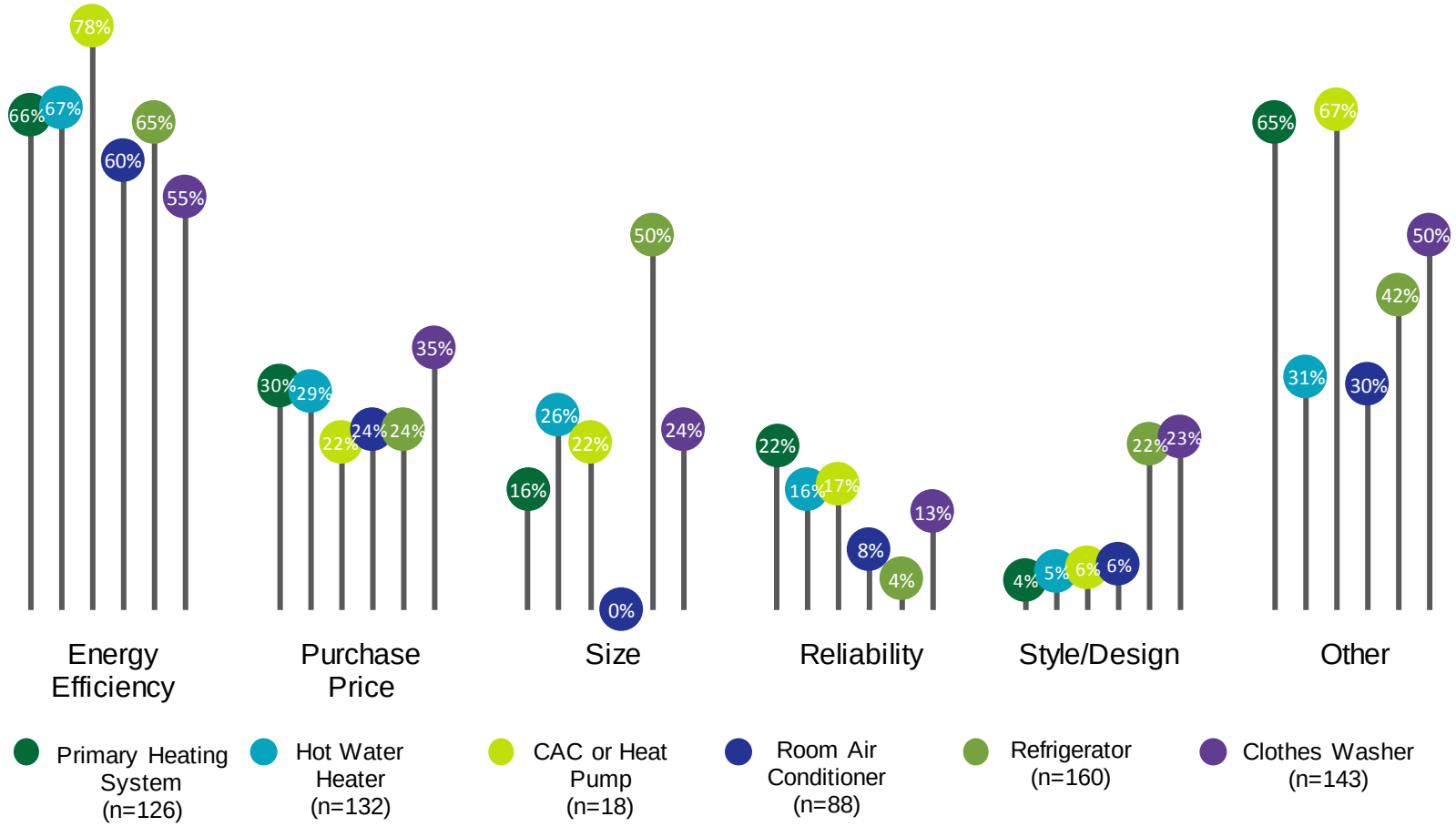
(Base: Respondents who replaced or installed product within past ten years)



Energy efficiency was the most common factor considered by respondents who replaced heating or cooling equipment in the past ten years. Over 60% of respondents said they considered energy efficiency when selecting a new primary heating system, hot water heater, or room air conditioner (Figure 22). The second most common factor when selecting heating or cooling equipment was purchase price, mentioned by 24% to 30% of respondents.

Energy efficiency was also the top factor considered by respondents who installed a refrigerator (65%) or clothes washer (55%) in the past ten years. Respondents also considered size, price, and style or design when selecting these appliances.

Figure 22: Factors Considered when Selecting New Products (multiple responses)

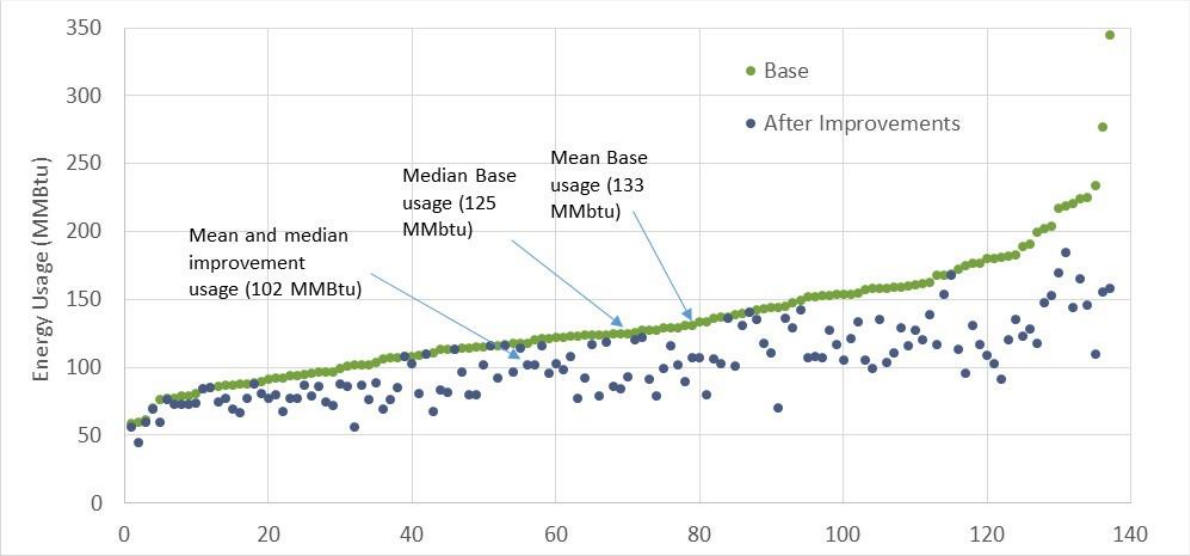


OBSERVED ENERGY SAVINGS OPPORTUNITIES IN AUDITED HOMES

This section provides a summary of the distribution and type of energy savings opportunities in Vermont single-family existing homes. It also provides three separate assessments of the savings opportunities from: 1) the Home Energy Score models, 2) the auditors perspective, and 3) measurements of key home characteristics.

The Home Energy Score (HES) is a Department of Energy rating system that models the energy efficiency of homes based on features of the building envelope, glazing, mechanical systems, and home area.[16] Figure 23 illustrates the larger energy savings opportunities that are available at homes with higher energy usage. The figure displays the HES-modeled annual energy consumption before and after all recommended HES improvements are implemented for each home sorted by base energy usage in ascending order. The average base energy usage is 133 MMBTu, which declines by 23% to 102 MMBtu after all recommended improvements.

Figure 23: Statewide Average Energy Consumption with and without Improvements



[16] The HES tool does not include lighting, appliances, or thermostat set points among its input variables.

Figure 24 displays the HES-modeled current annual energy usage and estimated energy savings by quartile. The first quartile represents the 25% of homes with the lowest annual energy consumption; in contrast, the fourth quartile represents the 25% of homes with the highest annual energy consumption. The 25% of homes in the fourth quartile are estimated to represent 36% of total energy consumption and 50% of the total energy savings. This analysis highlights the importance of targeting high consumption homes in reducing overall energy usage.

Figure 24: Distribution of Energy Usage and Savings by Quartile

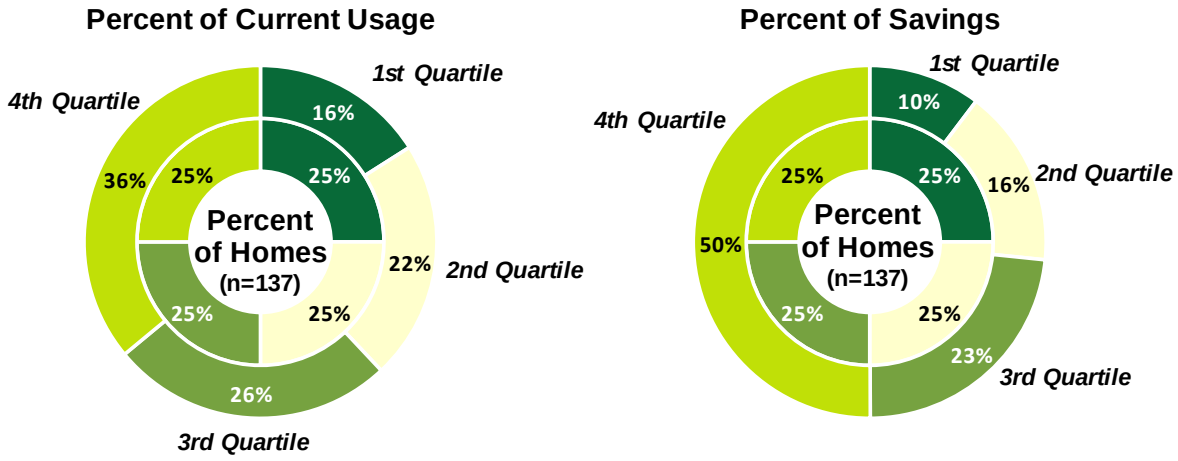


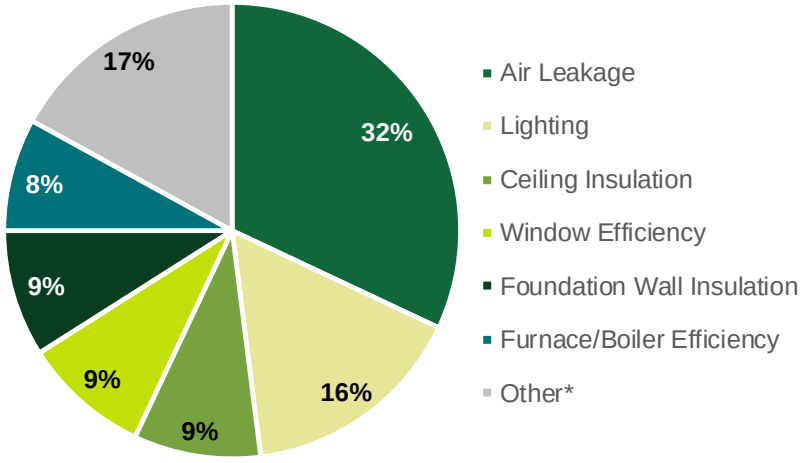
Table 6 summarizes the characteristics of various savings opportunities. Overall, a minority of homes present a substantial savings opportunity in each category, with the exception of water heater pipe insulation (64%) and manual thermostats (69%).

Table 6: Savings Opportunities

Characteristic	Measurement	Percent
Ceiling Insulation	Percent of homes with <= R-19 in flat ceilings	13%
	Percent of homes with <= R-19 in cathedral ceilings	23%
Wall Insulation	Percent of homes with no wall insulation	3%
Basement Insulation	Percent of homes with unconditioned basements that have uninsulated frame floors and foundation walls	45%
Windows	Percent of window area that is single pane	20%
	Percent of single pane window area that does not include storm windows	27%
Air Infiltration	Percent of homes > 10.0 ACH50	30%
HVAC	Percent of homes with a furnace or boiler > 20 years old	23%
	Percent of homes with manual thermostats	69%
Water Heaters	Percent of homes with tankless coil systems	8%
	Percent of homes with electric storage tanks	25%
	Percent of all storage tanks > 15 years old	34%
	Percent of homes without any pipe insulation	64%
Refrigerators	Percent of primary refrigerators 15 or more years old	28%
	Percent of secondary refrigerators 15 or more years old	46%
Lighting	Socket saturation of incandescent and halogen bulbs	43%

Figure 25 displays the distribution of the total energy efficiency opportunities identified by auditors. Auditors identified up to 14 energy efficiency opportunities per home, resulting in a total of 611 opportunities. Nearly one-third of the total energy efficiency opportunities identified pertain to air leakage (32%), followed by lighting (16%), ceiling insulation (9%), windows (9%), foundation wall insulation (9%), and boiler or furnace efficiency (8%).

Figure 25: Total 2016 Auditor Identified Energy Efficiency Opportunities



*Includes duct insulation/sealing, water heater efficiency, wall, frame floor, door, and knee wall insulation.

Table 7 displays the percent of homes containing auditor identified energy efficiency opportunities. Auditors identified air leakage opportunities in nearly three-quarters (74%) of on-site homes. Auditors identified lighting and window efficiency opportunities in over two-fifths of on-site homes (44% and 41%, respectively). Auditors identified furnace/boiler efficiency and foundation wall insulation opportunities in around one-third of on-site homes, and ceiling insulation opportunities in around one-quarter of on-site homes. Other energy efficiency opportunities were identified in less than one-fifth of on-site homes.

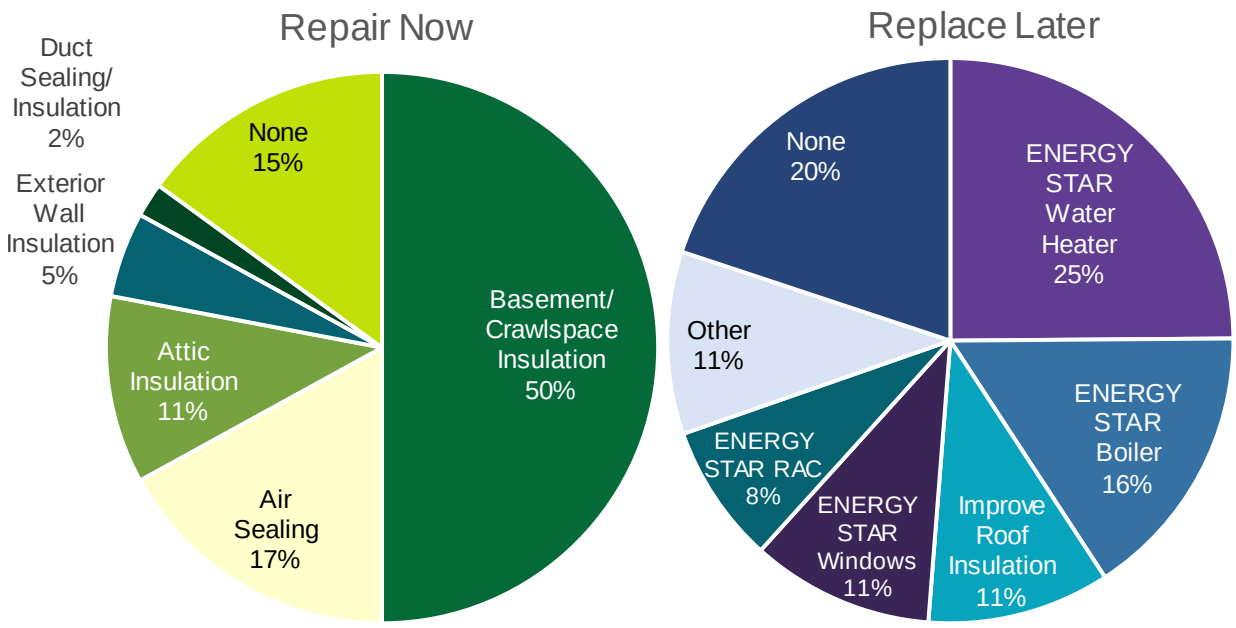
Table 7: Percent of Homes with Auditor Identified Energy Efficiency Opportunities

Energy Efficiency Opportunity	Percent of Homes
n	*140*
Air Leakage	74%
Lighting	44%
Window Efficiency	41%
Furnace/Boiler Efficiency (AFUE)	34%
Foundation Wall Insulation	31%
Ceiling Insulation	26%
Duct Insulation and Sealing	16%
Water Heater Efficiency	16%
Wall Insulation R-Values	6%
Frame Floor Insulation	6%
Door Insulation	<1%
Knee Wall Insulation	<1%
Other*	14%

*Includes duct insulation/sealing, water heater efficiency, wall, frame floor, door, and knee wall insulation.

The HES tool provides a list of *Repair Now*[17] and *Replace Later*[18] recommendations for each modeled home to improve the home's energy efficiency. Figure 26 displays the statewide distribution of the primary[19] *Repair Now* and *Replace Later* recommendations. Adding basement or crawlspace insulation was the primary *Repair Now* recommendation for one-half (50%) of the homes, followed by air sealing (17%) and attic insulation (11%). Installing an ENERGY STAR® water heater was the primary *Replace Later* recommendation for one-quarter (25%) of the homes, followed by installing an ENERGY STAR® boiler (16%), improving roof insulation (11%), and installing ENERGY STAR® windows (11%).

Figure 26: HES Primary Recommendations



*Includes ENERGY STAR® furnace, heat pump, CAC, and efficient wood stove.

EMERGING TECHNOLOGIES

This section provides findings regarding emerging technologies in Vermont from the interviews with HVAC distributors, HVAC contractors, and retailers as well as the homeowner surveys and on-site visits. These technologies include ductless mini-split heat pumps, HPWHs, high performance circulator pumps, furnaces with an ECM fan, solar hot water systems, central wood pellet furnaces and boilers, solar arrays, and HEMs. This section provides information on awareness, satisfaction, and market trends as well as opportunities for and barriers to the adoption of these emerging technologies.

[17] Improvements that "will save you money, conserve energy, and improve your comfort now."
[18] Improvements that "will help you save energy when it's time to replace or upgrade."
[19] The primary recommendation is the recommendation from each home associated with the largest annual energy cost savings.

The four distributor interviewees and ten contractor interviewees were asked about which types of equipment they sell or install, how many they sell or install of each type, and whether they are seeing any market trends in each of the product types they sell. All interviewees sold or installed ductless air source heat pumps and HPWHs. Almost all interviewees sold or installed high performance circulator pumps, furnaces with ECM fans, and ducted air source heat pumps. Fewer interviewees sold or installed ground source heat pumps, pellet systems, or solar hot water systems.

Table 8: Types of Equipment Sold or Installed During Past Two Years

Equipment Type		
	Distributors	Contractors
n	*4*	*10*
Ductless Air-Source Heat Pumps	4	10
Heat Pump Water Heaters	4	10
High Performance Circulator Pumps	4	9
Furnaces with ECM Fan	3	10
Ducted Air-Source Heat Pumps	3	9
Ground Source Heat Pumps	2	4
Central Wood Pellet Furnaces and Boilers	0	4
Solar Hot Water Systems	0	1

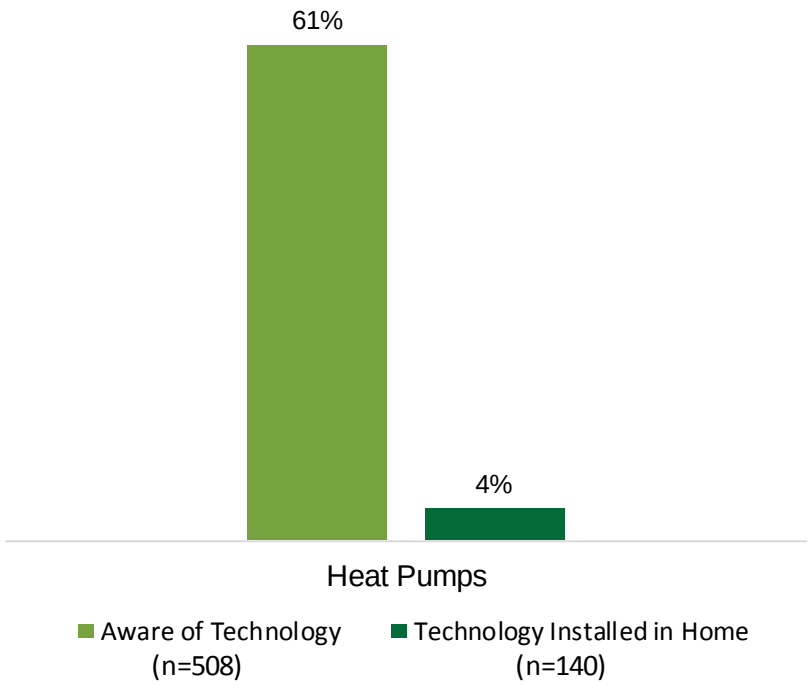
According to the contractors interviewed, most installations appear to meet Efficiency Vermont or ENERGY STAR® efficiency criteria. Ground source heat pumps (95%) and HPWHs (93%) were the most likely to meet the specifications. Contractors indicated that the single zone ductless heat pumps are more likely to meet Efficiency Vermont specifications (84%) than multi-zone models (73%). Of all furnaces installed, respondents estimated that 70% were equipped with an ECM motor.

Heat Pumps

The interviewed distributors thought that ductless heat pumps will continue to dominate sales, with most of them concurring that the rate of market growth will be impacted by the price of oil and gas (specifically, if oil and gas prices remain low, then market growth will be slower than otherwise). In addition, all of the interviewed contractors recommend heat pump technologies to customers for space heating. Four of the ten contractors recommend heat pumps for space heating all of the time, the remaining six were evenly split between recommending them most of the time or some of the time. All ten contractors indicated that customers agree with their recommendation of a heat pump for space heating most of the time.

Over three-fifths (61%) of surveyed homeowners were aware of heat pumps. Ductless heat pumps were installed in four percent of on-site homes. Most respondents with heat pumps installed in their homes were satisfied with the heat pump.

Figure 27: Heat Pump Awareness and Installations in Homes



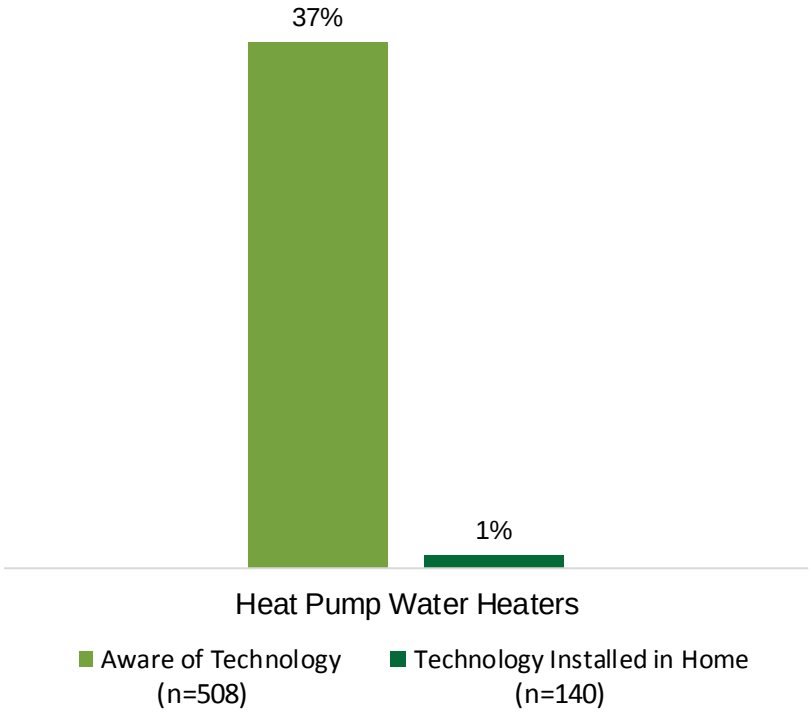
Heat Pump Water Heaters

Both market supply and consumer demand for HPWH systems is expected to increase over the next several years. Market supply is expected to increase due to technological advancements, improvements in energy efficiency, and wider availability. Consumer demand is expected to also increase due to price reductions, higher demand for energy efficiency, and the availability of rebates. However, improving consumer awareness of HPWHs is an essential component of the market forecast.

All of the interviewed contractors recommend heat pump technologies to customers for water heating. Seven of ten contractors recommend HPWHs some of the time, two most of the time, and one rarely. Eight of ten contractors indicated that customers agree with their recommendation of a heat pump for water heating most of the time. All three store managers recommended a HPWH “all the time” to consumers shopping for a new water heater. Two of the three interviewees stated that consumers agreed with their recommendation “most of the time,” though the expense of the system was an obstacle.

Thirty-seven percent of surveyed homeowners were aware of HPWHs, though HPWHs were installed in just one percent of on-site homes. Most respondents with HPWHs installed in their homes were satisfied with the HPWH. Customer satisfaction with HPWHs, as reported by the store managers, was positive overall; only one instance of negative feedback was reported from the three store managers interviewed.

Figure 28: Heat Pump Water Heater Awareness and Installations in Homes

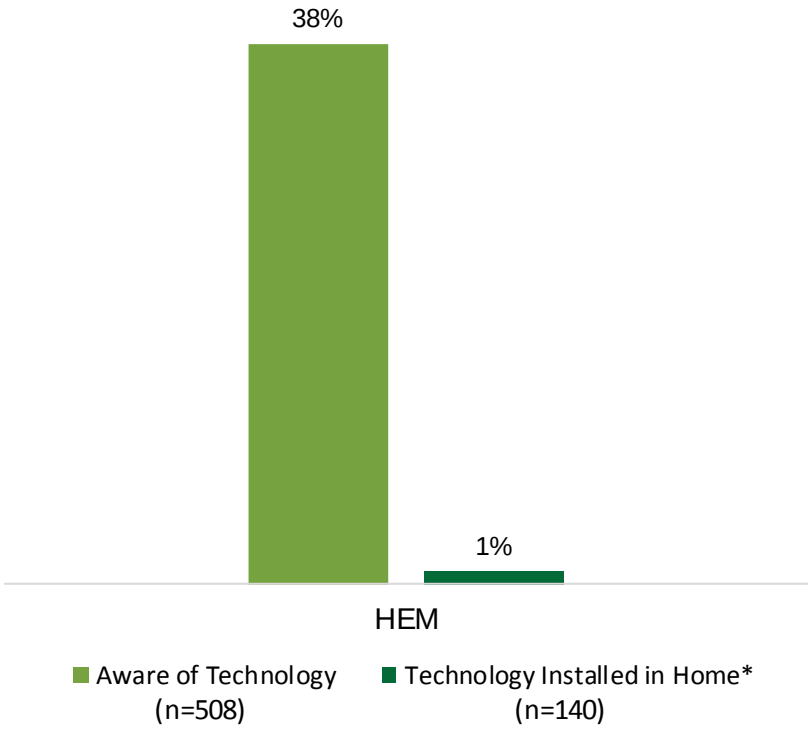


One of the goals of the on-site inspections was to assess the potential for HPWH installation in single-family homes. HPWH's require sufficient space, a minimum temperature of 50 degrees, and a drain in order to be installed. Just under one-third (30%) of the on-site homes meet all three requirements.

Home Energy Management Systems

According to two store managers interviewed, few consumers are aware of the HEMS technology before entering the store.[20] However, nearly two-fifths (38%) of surveyed homeowners were aware of HEMS. Wi-fi thermostats, one type of HEMS, were installed in less than one percent of on-site homes.

Figure 29: HEM Awareness and Installations in Homes



*Only includes wi-fi thermostats.

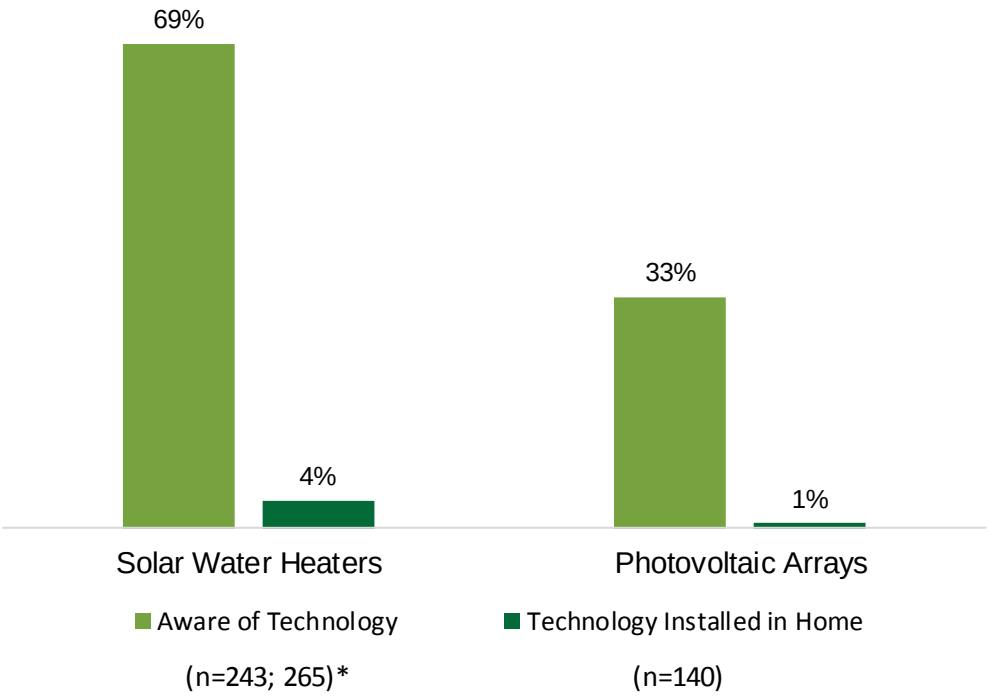
Consumer demand and market supply is expected to increase for HEMS over the next several years. The introduction of multifaceted products (such as integrated thermostat, lighting, and blind controls) and the development of open protocol systems (one application to control all systems) are expected to broaden consumer demand. Consumer awareness is considered essential to drive demand.

[20] Home energy management systems were defined to include products that control or monitor energy use in a home, such as smart thermostats and home automation systems.

Solar

Sixty-nine percent of surveyed homeowners were aware of "solar water heaters", including four percent who had them installed in their home. Thirty-three percent of respondents were aware of "photovoltaic arrays",[21] including one percent who had them installed in their homes. Most respondents with solar water heaters or photovoltaic arrays were satisfied or very satisfied.

Figure 30: Solar Water Heaters and Photovoltaic Arrays Installed in Homes



*n=243 for solar water heaters; n=265 for photovoltaic arrays.

Among those respondents who considered but did not install photovoltaic arrays or solar water heaters in their homes, the most common reason pertained to the cost of the equipment: over one-half said it was too expensive. The second most common reason respondents gave was that there wasn't enough sun or their properties were too shady.

Initial Experiences

The distributors were asked whether they had heard of any negative installation or performance issues with heat pumps (ducted, ductless, and ground source), HPWHs, central wood pellet furnaces and boilers, furnaces with ECM fans, high performance circulator pumps, and solar hot water systems. Distributors who had heard of issues with these systems were asked how frequently the problems occurred, how satisfied they

[21] Solar photovoltaic arrays are not eligible to be funded through the Energy Efficiency charge in Vermont.

thought the contractors were with the performance of these systems, and why. Two main themes emerged. First, when a product is new there have occasionally been some issues with the actual product. One example cited was for HPWHs: "When they first came out, there was a problem with every manufacturer with the compressors. There was probably a failure rate of about 80%." This has since been addressed, but some contractors "still seem to be hesitant to use [HPWHs] sometimes".

The second, and more widely prevailing theme, is summed up by one interviewee: "The only time I have had issues, it's a contractor install issue, or it's a contractor not understanding what he is installing because he has never installed it before, but he does it anyway because he wants to remain competitive."

The relationship between installation issues and contractor satisfaction levels is bidirectional: contractors are typically more satisfied with a technology that they are familiar with, is "quick and easy" to install, and that they receive few callbacks on. There exists a "chicken-and-egg" situation: contractors like technologies that they are confident with or are easy to install because their customers do not call them back to address issues and therefore the homeowners are assumed to be more satisfied with the contractor's work. Meanwhile, newer technologies that may be less familiar or require a learning curve reduce a contractors' confidence in their capabilities and increase their concern (and potentially the likelihood) about callbacks.

According to contractors, installation and performance issues appear to be uncommon. Six of the ten contractors reported experiencing issues with at least one of the emerging HVAC technologies. However, almost all respondents reported that these issues occurred rarely or only some of the time. The type of problems varied across contractors, in part due to the rarity of issues in the first place.

The contractors' perception of customer satisfaction was very positive—no contractor thought their customers were dissatisfied with the equipment installed. Six of ten contractors mentioned a lack of complaints as the reason for believing their customers are satisfied, often using this response generally for all equipment types. In addition, most interviewees believe their customers receive their anticipated level of energy savings most or all of the time, again citing a lack of complaints as well as positive feedback when they do speak with customers.

Technology Barriers and Adoption

According to the four distributors interviewed, many question areas - including whether or not there are installation issues, contractors are satisfied with the product and promoting emerging technologies – hinge upon contractor confidence with the product. Distributors generally felt that in order to increase contractor confidence with the product (how the product works and how best to install the product, etc.), considerably more education and training is needed for contractors. All of the distributors offer a variety of training opportunities, with some of them "handholding" contractors at job sites to assist in appropriate applications of technologies such as cold climate heat pumps.

If a policy goal in Vermont is to see greater penetration of emerging technologies such as ductless heat pumps, then a primary finding from the distributor interviews is that far greater education and training must be provided for (and, perhaps, *required of*) contractors regarding installation, application, problem solving, and how to provide homeowners with the tools to efficiently use the equipment. Not surprisingly, the role of financial offerings such as incentives and low interest loans can also fill a critical niche; for distributors who work in multiple states, they believe that the higher rebates and greater availability of low interest loan opportunities available in neighboring states do increase customer uptake, and that if Vermont were to offer these more robustly then the Vermont market would grow more quickly.

Contractors believe the most effective way to encourage customers to purchase emerging HVAC technologies centers on cost savings or efficiency gains and the use of rebates. Eight of the ten interviewed contractors thought that Vermont efficiency programs were adequately supporting emerging technologies. However, when asked how efficiency programs in Vermont could better support heat pump technologies, four contractors suggested higher rebates.

Retailers indicated that lack of education regarding HPWHs and HEMs is a major obstacle. A majority of consumers do not appear to understand the long-term energy savings potential of HPWH systems. For HEMS, lack of understanding on how the technology works is an impediment. However, cost is the primary obstacle for both HEMS and HPWH systems. The continuation of rebates for HPWHs will incentivize consumers to adopt HPWH systems rather than conventional models. In addition, support of educational campaigns for both HPWHs and HEMS can build customer awareness of their energy and cost savings and encourage market adoption. Because HEMS are in their infancy, Efficiency Vermont support may foster market adoption in the following ways:

- Educational campaign to build awareness regarding their capabilities to reduce energy usage.
- Provide support for third party studies on the energy savings of HEMS to validate these technologies.
- Offer best practice guides on how HEMS can reduce energy consumption.

A Appendix A Comparison to Prior Baseline Studies

Table 9 compares key characteristics from the 2008 and 2011 baseline studies to the results of the current baseline study. For the most part, the data are similar given the lapse of about three years between studies. However, there are a few items with a noticeable difference:

- The proportion of homes with programmable thermostats increased from 24% to 33% to 39%
- The proportion of dishwashers that are ENERGY STAR® increased from 16%-18% to 45%
- The proportion of clothes washers that are ENERGY STAR® increased from 17% to 25% to 44%
- The proportion of homes with LEDs increased from 4% to 58%
- The proportion of light bulbs that are LEDs increased from <1% to 11%

Table 9: Comparison to Prior Baseline Study Results

Characteristic	Criteria	2008	2011	2016
Home Type	% of homes that are SF detached	98%	95%	95%
Age of Home	Average age (years)	60	66	61
Conditioned Floor Area	Average s.f.	2,213	1,972	2,147
Wall Insulation	Average R-value	11.9	13.4	12.8
Flat Ceiling Insulation	Average R-value	26.9	27.9	30.1
Cathedral Ceiling Insulation	Average R-value	20.8	20.5	20.6
Foundation Wall Insulation >50% above grade	Average R-value	11.1	11.3	13.0
Air Infiltration	Average ACH50	9.8	7.6	9.5
Heating System Efficiency	Average efficiency of oil boilers	82%	85%	84%
	Average efficiency of gas boilers	85%	86%	89%
	Average efficiency of oil furnaces	83%	83%	81%
	Average efficiency of gas furnaces	86%	89%	90%
Thermostats	% homes with programmable units	24%	33%	39%

Characteristic	Criteria	2008	2011	2016
Duct Insulation	% of homes with insulated ducts in uncond. space	10%	19%	6%
Water Heater Efficiency	Average Energy Factor for integrated tanks	79%	80%	80%
Hot Water Piping Insulation	% of homes with pipe insulation	20%	24%	36%
Refrigerators	% units that are ENERGY STAR®	23%	7%	22%
Dishwashers	% units that are ENERGY STAR®	18%	16%	45%
Clothes washers	% units that are ENERGY STAR®	17%	25%	44%
Separate freezers	% units that are ENERGY STAR®	3%	9%	10%
Lighting	% homes with CFLs installed	90%	92%	99%
	% bulbs that are CFLs	19%	30%	36%
	% homes with LEDs installed	n/a	4%	58%
	% bulbs that are LEDs	n/a	<1%	11%